Instruction Handbook for....

TYPE 74A AUTOMATIC NOISE FIGURE INDICATOR

Part Number 07410

January 1967

CUTLER-HAMMER

AIRBORNE INSTRUMENTS LABORATORY
DEER PARK, LONG ISLAND, NEW YORK 11729

CONTROL AIL DIVISION

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WARRANTY

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I. INTRODUCTION

The AIL Type 74A Automatic Noise Figure Indicator (ANFI) (Figure 1) is a device that, when used with an appropriate AIL Type 70 Noise Generator, provides a continuous and direct meter reading of the noise figure of a device under test. Type 70 Noise Generators, covering a 10-Mc to 40-Gc range, are available for use with the ANFI for automatic or manual measurement of noise figure.

The continuous indication of the noise figure of the device under test permits adjustment of the circuit parameters for minimum noise figure. The device under test may be a complete receiver (radar, television, telemetering, etc.), an amplifier (traveling-wave tube type, reactance type, etc.) or an IF amplifier. The simplicity of operation and the accuracy of indication makes the ANFI suitable for use both in the laboratory or in production operations.

With the addition of the AIL Type 30 Precision IF Attenuator, the ANFI can be used to make manual (Y-factor) measurements of noise figure.

FIGURE 1. AUTOMATIC NOISE FIGURE INDICATOR

II. SPECIFICATIONS

Noise figure ranges:		
Low	0 to 25 db	Both ranges extended to infinity
High	23 to 36 db	
Noise figure accuracy*:		
Low range		±0.5 db
High range		±1 db
Gain control range (manual and automatic)		65 db minimum
AGC output (nominal)		-2 to -6 volts
Sensitivity**		
(Part No. 07422)		100 μv
(Part No. 07423)		50 μv
(Part No. 07424)		100 μv
(Part No. 07426)		100 μv
Meter function		Noise figure (two ranges), second-detector current, or noise-generator current
Power output		Sufficient to operate the AIL Type 70 Noise Diode and Gas-Discharge Noise Generators in both the automatic and manual modes
Recorder output		0 to 0.25 volt DC, 10,000 ohms, ungrounded
Input power		115/230 volts ±10 percent, 50 to 60 cps at 1.8/0.9 amp
Size		Width 19 inches Height 8-3/4 inches Depth 14 inches
Mounting dimensions		See Figure 2 on page 3
Weight		44 pounds

* Tracking accuracy (direct reading comparison with a manual measurement), not absolute accuracy.

** Minimum signal required to obtain AGC in ANFI, when used with the indicated IF amplifier of the Appendices.

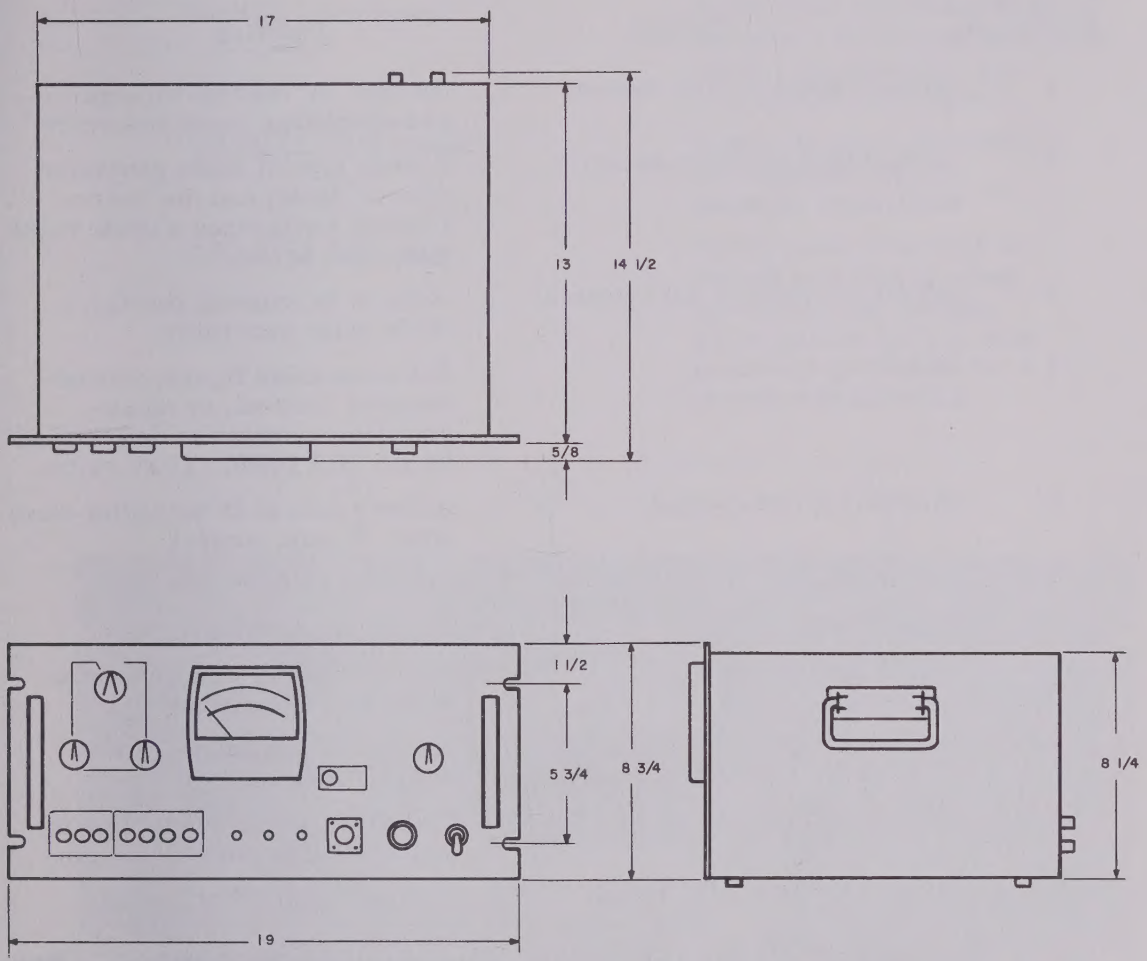


FIGURE 2. OUTLINE AND MOUNTING DIMENSIONS

III. OPERATING CONTROLS, INDICATORS, AND CONNECTORS

Index No. (Figure 3)	Control	Function
1	GAS-CURRENT ADJ. control	Adjusts DC current through a gas-discharge noise generator
2	GAS-DIODE selector switch	Selects type of noise generator (gas or diode) and the meter-current range when a diode noise generator is used
3	DIODE-CURRENT ADJ. control	Adjusts DC current through a diode noise generator
4	Meter	Indicates noise figure, second-detector current, or noise-generator current as determined by METER INDICATION switch
5	MANUAL GAIN control	Adjusts gain of IF amplifier when under manual control
6	Power ON-OFF switch	Controls primary power
7	POWER lamp	Indicates presence of power
8	DIODE POWER jack	Provides power connection for diode noise generator
9	IF INPUT jack	Input to IF amplifier from device under test
10	Cathode connector	Provides cathode connection to gas-discharge noise generator
11	METER INDICATION switch:	Controls meter function as follows:
	CURRENT-NOISE GEN button	Meter monitors noise-generator current
	CURRENT-2ND DET button	Meter monitors second detector DC current
	NF RANGE - DB 23 - 36 button	Meter reads noise figure on 23 to 36 db scale
	NF RANGE - DB 0 - 25 button	Meter reads noise figure on 0 to 25 db scale
12	Anode connector	Provides anode connection to gas-discharge noise generator

Index No. (Figure 3)	Control	Function
13	NOISE GENERATOR switch	Controls noise-generator mode as follows:
	MANUAL-ON button	Fires noise generator and permits it to run continuously. (IF amplifier gain is manually controlled.)
	MANUAL-OFF button	Turns off noise generator (IF amplifier gain is manually controlled)
	AUTO NF-ON button	Turns noise generator on and off at a rate of about 350 cycles per second. (IF amplifier gain is automatically controlled for a preset output level.)

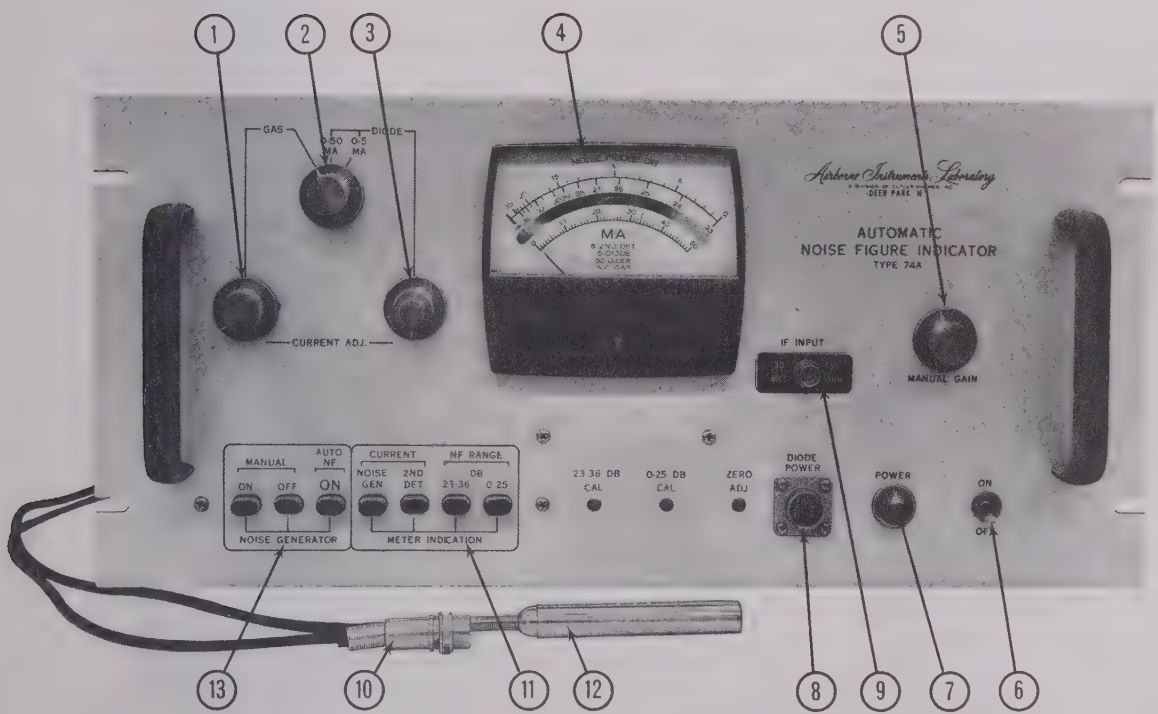


FIGURE 3. OPERATING CONTROLS, INDICATORS, AND CONNECTORS

IV. IF AMPLIFIER INSTALLATION

Before the ANFI can be used, the proper IF amplifier must be selected and installed. Four standard plug-in IF amplifiers (see the Appendices) are available for use with the ANFI:

Part No.	Center IF Frequency (Mc)
07422	10, 20 to 60 tunable
07423	30
07424	30, 40 to 180 tunable
07426	60

To install the IF amplifier, proceed as follows:

a. Loosen two thumb screws and remove top cover of ANFI.

b. Remove four rubber feet and remove bottom cover.

c. Bolt IF amplifier to ANFI chassis, using two bolts provided with IF amplifier.

d. Connect power (J1) and video (J2) cables to IF amplifier.

e. Replace top and bottom covers.

If IF amplifier Part No. 07422 or 07424 is used, tune the ANFI to the desired operating frequency as follows:

a. Connect a signal generator, tuned to the desired operating frequency, to input jack J1.

b. Press NOISE GENERATOR-MANUAL-OFF button.

c. Press METER INDICATION-CURRENT-2ND DET button.

d. Turn power on.

e. Set MANUAL GAIN control at mid range.

f. Adjust FREQ ADJ control shaft for a maximum indication on ANFI meter. Adjust output of signal generator for an approximate mid-scale reading on ANFI meter. Readjust FREQ ADJ control to a peak level.

V. OPERATING INSTRUCTIONS

A. AUTOMATIC NOISE FIGURE MEASUREMENT USING GAS-DISCHARGE NOISE GENERATOR

1. EQUIPMENT SETUP

a. Set up equipment as shown in Figure 4.

b. Set GAS-DIODE selector switch to GAS.

c. Set GAS-CURRENT ADJ. control fully counterclockwise.

d. Press NOISE GENERATOR-MANUAL-OFF button.

e. Set MANUAL GAIN control fully counterclockwise (minimum gain).

f. Set power ON-OFF switch to ON and allow 15 minutes for equipment to warm up.

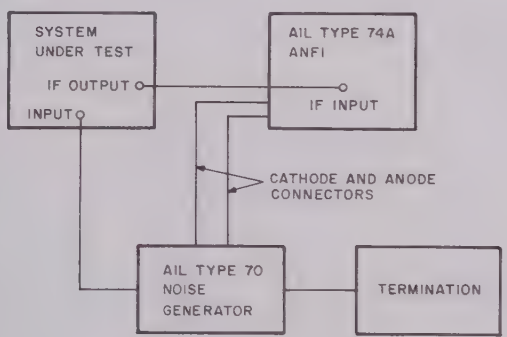


FIGURE 4. SETUP FOR AUTOMATIC NOISE FIGURE MEASUREMENT USING GAS-DISCHARGE NOISE GENERATOR

2. MEASUREMENT PROCEDURE

a. Press METER INDICATION-CURRENT-2ND DET button.

b. Press NOISE GENERATOR-AUTO NF-ON button and note meter indication. Make certain that it is within two divisions of full scale (if it is not, see Section VII, Maintenance). This indicates that AGC circuits within ANFI have control.

c. Press METER INDICATION-CURRENT-NOISE GEN button.

d. Press NOISE GENERATOR-MANUAL-ON button. "

e. Set GAS-CURRENT ADJ. control to current setting given in handbook for gas-discharge noise generator being used.

f. Press NOISE GENERATOR-AUTO NF-ON button.

g. Press one of the METER INDICATION-NF RANGE-DB buttons (either 23 - 36 or 0 - 25), depending upon expected range of measured noise figure.

h. Read noise figure of system under test on appropriate meter scale.

CAUTION

See the appropriate Noise Generator handbook to determine if the noise source in use has an Excess Noise Ratio (db) of 15.3. If it does not, the noise figure measured must be corrected in accordance with instructions in the Noise Generator handbook.

B. AUTOMATIC NOISE FIGURE MEASUREMENT USING DIODE NOISE GENERATOR

1. EQUIPMENT SETUP

a. Connect equipment as shown in Figure 5.

b. Set GAS-DIODE selector switch to DIODE 0 - 50 MA.

c. Set DIODE-CURRENT ADJ. control fully counterclockwise.

d. Set MANUAL GAIN control fully counterclockwise.

e. Press NOISE GENERATOR-MANUAL-OFF button.

f. Set power ON-OFF switch to ON and allow equipment to warm up for 15 minutes.

2. MEASUREMENT PROCEDURE

a. Press METER INDICATION-CURRENT-2ND DET button.

b. Press NOISE GENERATOR-AUTO NF-ON button and note the meter indication. Make certain that it is within two divisions of full scale (if it is not, see Section VII). This indicates that AGC circuits within the ANFI have control.

c. Press METER INDICATION-CURRENT-NOISE GEN button.

d. Press NOISE GENERATOR-MANUAL-ON button.

e. Set DIODE-CURRENT ADJ. control to obtain a meter reading of 33.8 ma.

NOTE

The diode current will drift considerably when first turned on. Sufficient warm-up time should be allowed so that the diode current stabilizes at 33.8 ma.

f. Press NOISE GENERATOR-AUTO NF-ON button.

g. Press one of the METER INDICATION-NF RANGE-DB buttons (either 23 - 36 or 0 - 25, depending upon the expected range of measured noise figure).

h. Read noise figure of system under test on appropriate meter scale.

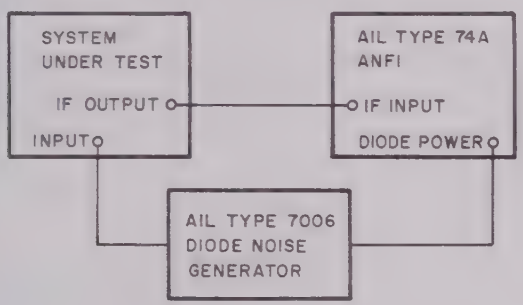


FIGURE 5. SETUP FOR AUTOMATIC NOISE FIGURE MEASUREMENT USING DIODE NOISE GENERATOR

C. MANUAL NOISE FIGURE MEASUREMENT (Y-FACTOR) USING GAS-DISCHARGE NOISE GENERATOR

1. EQUIPMENT SETUP

a. Set up equipment as shown in Figure 6.

b. Set GAS-DIODE selector switch to GAS.

c. Set GAS-CURRENT ADJ. control fully counterclockwise.

d. Press NOISE GENERATOR-MANUAL-OFF button.

e. Set MANUAL GAIN control fully counterclockwise (minimum gain).

f. Set power ON-OFF switch to ON and allow 15 minutes for equipment to warm up.

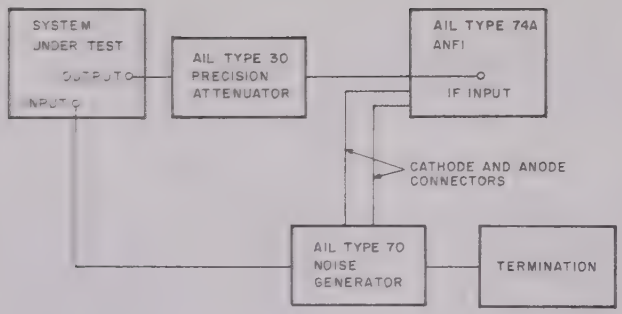


FIGURE 6. SETUP FOR MANUAL NOISE FIGURE MEASUREMENT USING GAS-DISCHARGE NOISE GENERATOR

2. MEASUREMENT PROCEDURE

a. Press METER INDICATION-CURRENT-2ND DET button.

b. Adjust precision attenuator and/or MANUAL GAIN control for a convenient 2ND DET reference level reading on meter. Note reference level and precision attenuator setting.

c. Press METER INDICATION-CURRENT-NOISE GEN button.

d. Press NOISE GENERATOR-MANUAL-ON button.

e. Set GAS-CURRENT ADJ. control to current setting given in handbook for gas-discharge noise generator being used.

f. Press METER INDICATION-CURRENT-2ND DET button.

g. Increase setting of precision attenuator until second detector current returns to reference level noted in step b.

h. Subtract attenuator reading noted in step b from present reading. The difference is the Y-factor.

i. Press NOISE GENERATOR-MANUAL-OFF button, reset precision attenuator to original setting, and check that meter returns to original reading when precision attenuator is reset to original setting. The noise figure of the system under test can be computed from

$$F = \frac{\left(\frac{T_d}{T_o} - 1\right)}{Y - 1}$$

where

T_d = effective temperature of the noise generator in the "ON" condition (degrees Kelvin),

T_o = 290 degrees Kelvin,

Y = ratio of the noise output power of the receiver, with the noise generator "ON," to that with the noise generator "OFF."

Noise figure in db is given by:

$$F_{db} = 10 \log\left(\frac{T_d}{T_o} - 1\right) - 10 \log (Y - 1)$$

j. In lieu of actual computation, noise figure can be determined from Figure 7 if noise source has a T_{ex} of 15.3 db. If it does not, noise figure can be determined from the graph as follows. When

$$T_{ex} = \frac{T_d}{T_o} - 1$$

(1) Determine noise figure from graph, assuming a T_{ex} of 15.3 db.

(2) The correct noise figure is determined from

$$F_{actual} = F + T_{ex} - 15.3 \text{ in db}$$

where

F_{actual} = corrected noise figure in db,

F = noise figure from graph in db.

D. MANUAL NOISE FIGURE MEASUREMENT (3-DB METHOD) USING DIODE NOISE GENERATOR

1. EQUIPMENT SETUP

a. Set up equipment as shown in Figure 8.

b. Set GAS-DIODE selector switch to DIODE 0-5 MA.

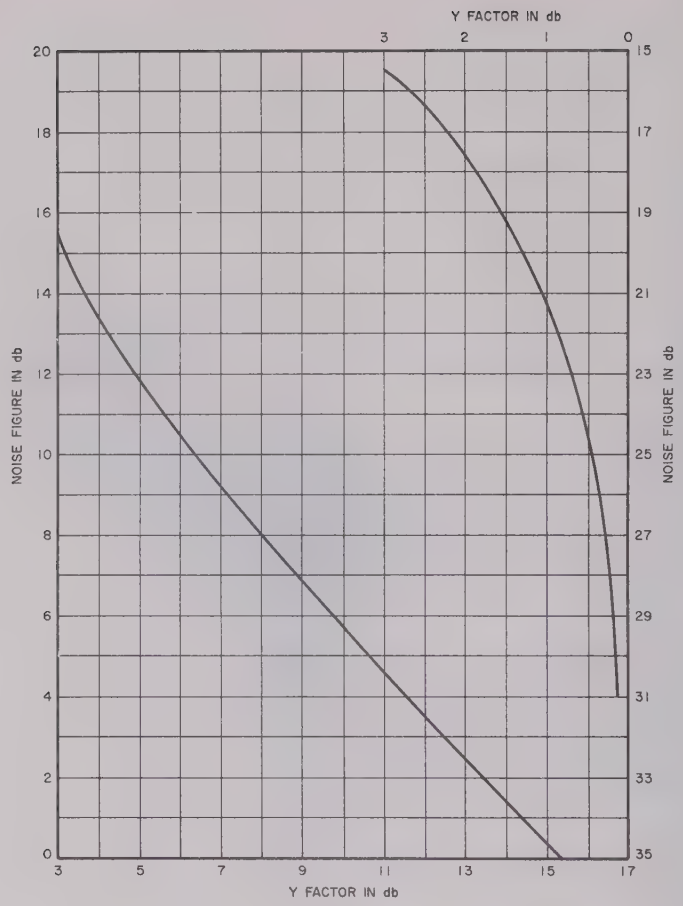


FIGURE 7. Y-FACTOR VS NOISE FIGURE FOR A 15.3-db NOISE SOURCE

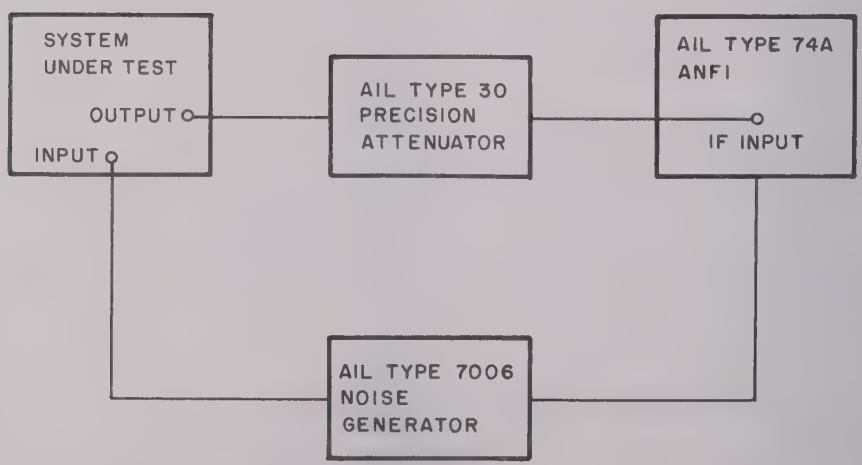


FIGURE 8. SETUP FOR MANUAL NOISE FIGURE MEASUREMENT (3-DB METHOD) USING DIODE NOISE GENERATOR

c. Set DIODE-CURRENT ADJ. control fully counterclockwise.

d. Set MANUAL GAIN control to about mid range.

e. Press NOISE GENERATOR-MANUAL-OFF button.

f. Press METER INDICATION-CURRENT-2ND DET button.

g. Set precision attenuator to 0 db.

h. Set power ON-OFF switch to ON and allow 15 minutes for equipment to warm up.

2. MEASUREMENT PROCEDURE

a. Adjust precision attenuator and/or MANUAL GAIN control for a second detector meter reading of at least 2/3 scale.

b. Increase setting of precision attenuator exactly 3 db.

c. Press NOISE GENERATOR-MANUAL-ON button.

d. Turn DIODE-CURRENT ADJ. control clockwise until meter again indicates reference level noted in step a.

e. Press METER INDICATION-CURRENT-NOISE GEN button, and note diode current.

NOTE

If meter pointer goes off scale, set GAS-DIODE selector switch to 0 - 50 MA position.

f. Compute noise figure of equipment under test, using:

$$F = 10 \log I_d$$

where I_d = diode current in ma. Figure 9 can be used to determine the noise figure in db in lieu of the actual calculation.

E. ACCURACY CONSIDERATIONS

1. NOISE GENERATOR ERROR

Noise figure measurements assume an accurate knowledge of T_{ex}, the relative excess noise temperature of the noise source. In the case of gas-discharge noise generators, this value is a function of various physical characteristics (see

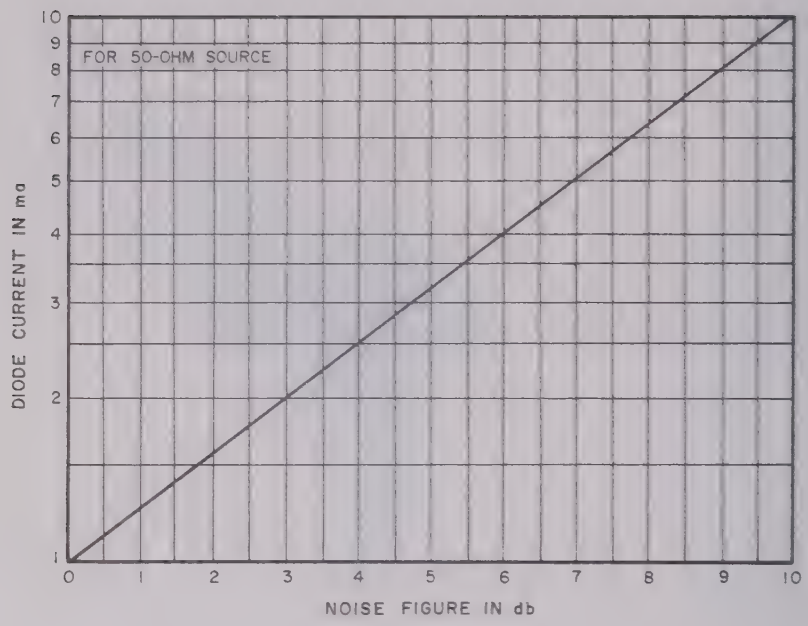


FIGURE 9. DIODE CURRENT VS NOISE FIGURE

Section VI, Theory of Operation). In general, the noise power output is not necessarily the same for all noise generators or constant over the entire frequency range. Refer to the handbook for the noise generator being used to determine the proper correction factor at the test frequency. This correction in db is algebraically added to the measured noise figure expressed in db.

2. NOISE GENERATOR TERMINATION TEMPERATURE

The derivation of the equation for noise figure is based on the termination being at a temperature equal to T_o (290^oK), the reference temperature. If this condition is not met, the measured value of noise figure must be adjusted. The extent of this adjustment can be determined from Figure 10. This correction in db is algebraically added to the measured noise figure expressed in db.

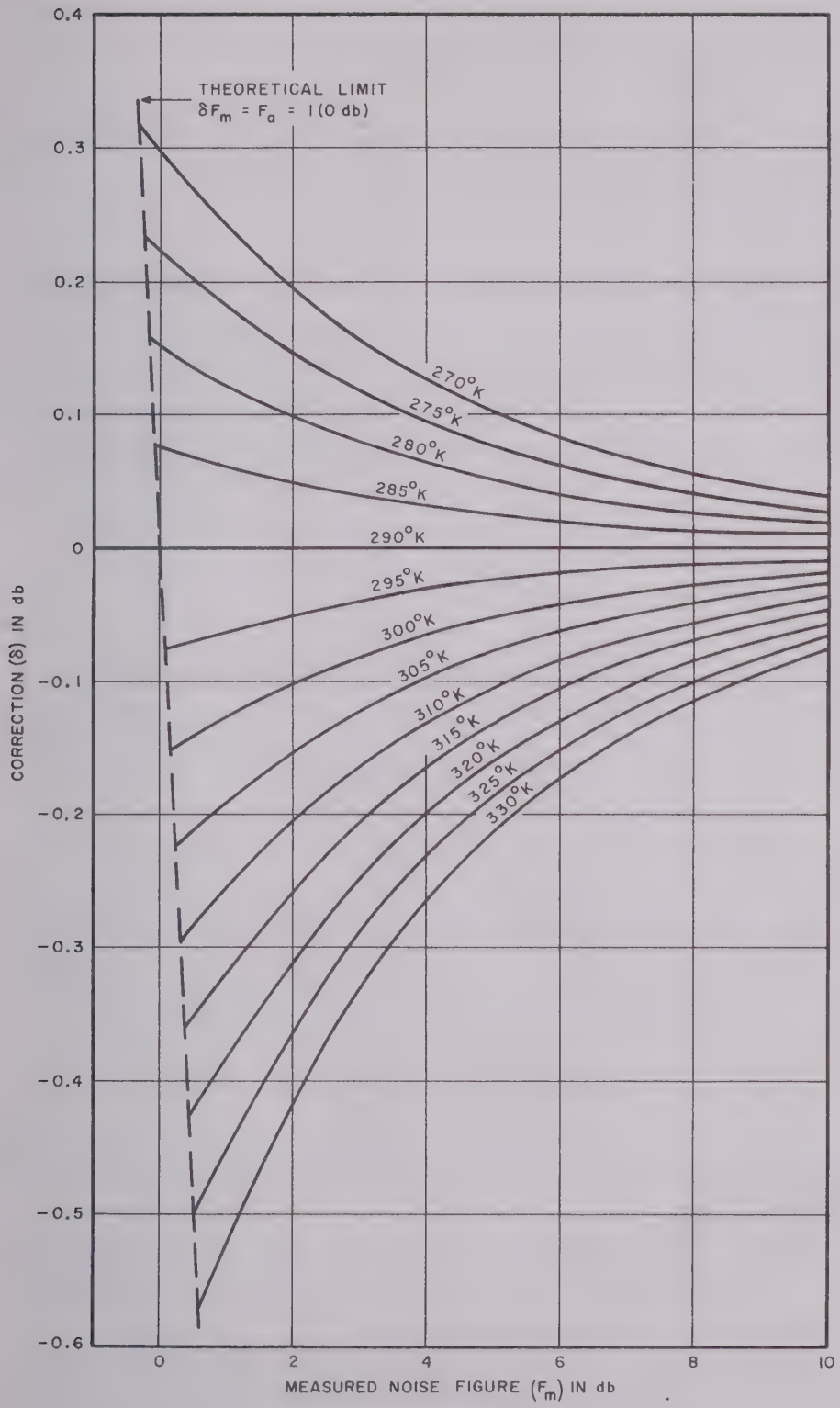


FIGURE 10. TERMINATION TEMPERATURE CORRECTION

F. CONVERTING TO 230-VOLT OPERATION

When delivered, the ANFI is wired for 115-volt input operation. To convert the unit to 230-volt input operation, the parallel-connected primaries of transformers T1 and T2 must be series-connected and the 3-ampere fuses F1 and F2 must be replaced by 1.5-ampere fuses.

The rewiring of the transformers can be accomplished at the terminal strip shown in Figure 11. The input power is connected across terminals 1 and 4. For 115-volt operation, jumpers connect terminals 1 to 3 and 2 to 4; to convert to 230-volt operation, remove one jumper and connect the remaining jumper between terminals 2 and 3. Replace the 3-ampere Slo-Blo fuses with 1.5-ampere Slo-Blo fuses.

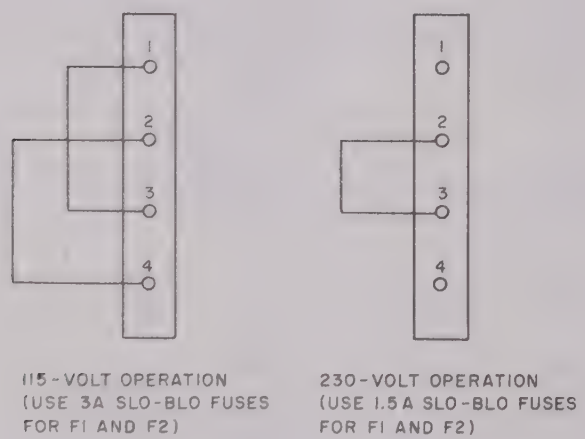


FIGURE 11. TERMINAL BOARD WIRING FOR 115- OR 230-VOLT OPERATION

VI. THEORY OF OPERATION

A. GENERAL

1. NOISE FIGURE

Noise figure can be qualitatively defined as a ratio that compares the noise power available at the output of a network with that which would be available at the output of an ideal noiseless network of otherwise identical characteristics. This can be expressed mathematically as in equation 6-1.

$$F = \frac{S_i/N_i}{S_o/N_o} = \frac{N_o}{GN_i} \qquad (6\text{-}1)$$

where the terms S and N are available signal and noise powers respectively, and the subscripts indicate input or output; the ratio S_o/S_i is simply the available power gain, G, of the network. Making this substitution and rearranging,

$$N_o = N_i FG \qquad (6\text{-}2)$$

The noise power available at the input is that generated by the input termination and can be written

$$N_i = KT_oB \qquad (6\text{-}3)$$

where

K = Boltzmann's constant = 1.38×10^{-23} joules/^oK,

B = bandwidth in cps,

T_o = input termination temperature (assuming room temperature of 290^{o}K).

NOTE

All temperatures in these equations are expressed as absolute temperatures (degrees Kelvin) and are related to the Centigrade scale as follows:

$$^oK = {}^oC + 273$$

Substituting in equation 6-2,

$$N_o = KT_oBFG \tag{6-4}$$

Expansion of this relation yields

$$N_o = [KT_oB + (F - 1)KT_oB]\, G \tag{6-5}$$

Although equation 6-5 expresses noise figure implicitly in terms of its effect on the network output, it is sometimes considered more basic than equation 6-1 because:

a. It can be used to account for the possibility of input termination temperature differing from the reference temperature, T_o.

b. It can be conveniently represented pictorially.

c. It provides the basis for an indirect, but convenient, method of measuring noise figure.

Figure 12A is a representation of equation 6-5. Noise source A is the input termination. In addition, noise source B is a fictitious source that represents the network's contribution to the noise output, referred to the input. It should be noted that the definition of noise figure is based on the reference temperature, T_o (290^oK). The effect of varying input termination temperature is discussed in subsequent paragraphs.

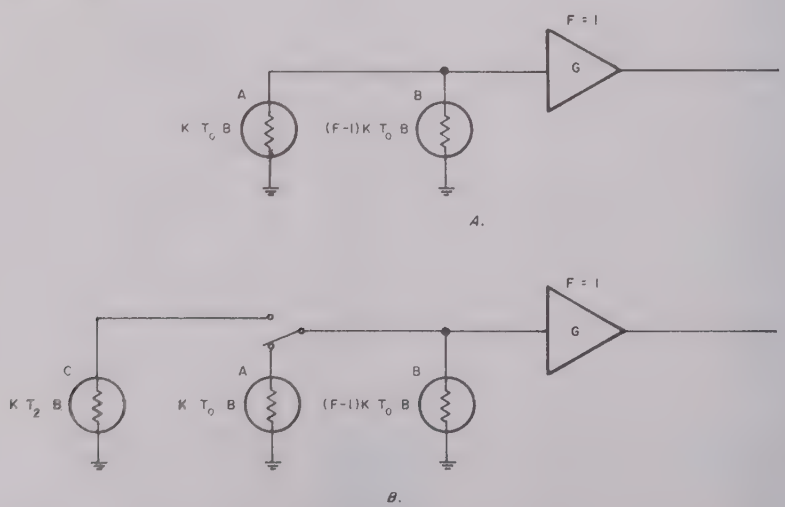


FIGURE 12. EQUIVALENT REPRESENTATION OF A NOISY NETWORK

2. NOISE FIGURE MEASUREMENT (GENERAL)

Figure 12A can be modified as indicated in Figure 12B. A switch is added so that the original input termination (A) can be disconnected and the network input terminated in a second source (C) at a temperature T_2 (the temperature of the gas-discharge noise generator usually). The available output power of the network for this condition is given by equation 6-6.

$$N_{o2} = [KT_2B + KT_oB\ (F - 1)]\ G \tag{6-6}$$

Dividing equation 6-6 by equation 6-4

$$\frac{N_{o2}}{N_{o1}} = \frac{T_2 + T_o\ (F - 1)}{T_oF} \tag{6-7}$$

Adding -1 to both sides and rearranging terms,

$$F = \frac{\left(\frac{T_2}{T_o} - 1\right)}{\left(\frac{N_{o2}}{N_{o1}} - 1\right)} \tag{6-8}$$

Equation 6-8 is the basic relation for determining noise figure. The term $T_2/T_o - 1$ is called relative excess noise temperature and is usually expressed simply as T_{ex}. It represents the relative increase in noise power at the network input when the switch is operated. If T_{ex} is known, then the ratio N_{o2}/N_{o1} (commonly called Y factor) can be measured and noise figure computed from equation 6-8. Note that it is not necessary to measure the absolute power levels at the network output, merely their ratio.

3. MANUAL NOISE FIGURE MEASUREMENT

There are several methods of measuring Y factor and, indirectly, noise figure. However, only the two most common methods will be discussed.

a. CONSTANT EXCESS NOISE (Y FACTOR)

This is probably the most widely accepted method of determining noise figure. Figure 13 is a block diagram showing the basic setup of equipment. The noise generator can be any one of a number of devices of known relative excess noise temperature. The most common are: (1) the gas-discharge lamp, where the relative excess noise temperature is primarily a function of the type of gas, the diameter of the discharge column, and the gas pressure; and (2) the thermionic diode, which has a relative excess noise temperature that is a function of the DC diode current and the terminating source resistance. When the noise generator is turned off, the input of the receiver under test sees a passive termination at T_o and the detector level meter indicates some value indicative of N_{o1} in equation 6-8. When the noise generator is turned on, the output level will increase because of the increase of noise at the input. This new level is indicative of N_{o2}. If the attenuation between the receiver output and the detector is increased until the detector level is the same as with the noise source off, then this increase is the Y factor (N_{o2}/N_{o1}) expressed in db (assuming the attenuator is calibrated in db). This value can then be converted to a power ratio, substituted in equation 6-8, and the receiver noise figure computed.

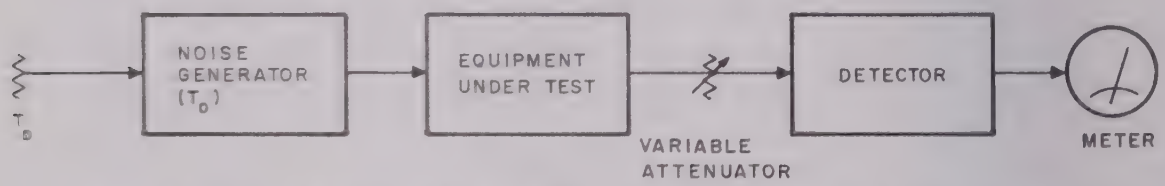


FIGURE 13. BLOCK DIAGRAM OF EQUIPMENT SETUP FOR DETERMINING NOISE FIGURE

b. CONSTANT Y FACTOR (3-DB METHOD)

The setup for this type of measurement is identical to that described in paragraph 3-a; however, after the initial output level with the noise source off is noted, the attenuation is increased exactly 3 db and the relative excess noise temperature of the source is then varied to obtain the same output level. A Y factor of 3 db is equivalent to a power ratio of 2. Substituting this value into equation 6-8 yields

$$F = \frac{T_{ex}}{2-1} = T_{ex} \qquad (6-9)$$

This method is generally used at lower frequencies (10 to 250 Mc) with a noise generator such as the thermionic diode (AIL Type 07006), where the relative excess noise temperature can be conveniently varied and easily determined from equation 6-10.

$$T_{ex\ (diode)} = 20 I_d R \tag{6-10}$$

where

I_d = diode plate current,

R = terminating resistor.

Substituting equation 6-10 into equation 6-9 yields

$$F = 20 I_d R \tag{6-11}$$

4. AUTOMATIC NOISE FIGURE MEASUREMENT

The preceding paragraphs derived the procedure for performing noise figure measurements. It is evident that if a large number of measurements are required, or if the noise figure is being used as a measure of system performance while the system is being tuned or set up, these methods can become quite cumbersome. The requirements for an automatic noise figure indicator are shown in general block diagram form in Figure 14. The first requirement of this type of system is a method of periodically turning the noise generator on and off. This is accomplished by a modulator driven by a gate generator, usually a free-running square-wave generator (multivibrator) operating at a low audio frequency. The output of the receiver consists of square-wave modulated noise. As in manual measurement, the two levels of the square wave represent receiver noise and receiver-plus-generator noise. This signal is amplified and then detected by the video detector. The AGC amplifier operates in such a manner that the average level of the square wave at the detector output remains constant. The peak-to-peak amplitude of the square wave is then measured by the synchronous detector, and the resultant voltage is displayed on a meter. That this voltage difference is a measure of noise figure can be shown as follows.

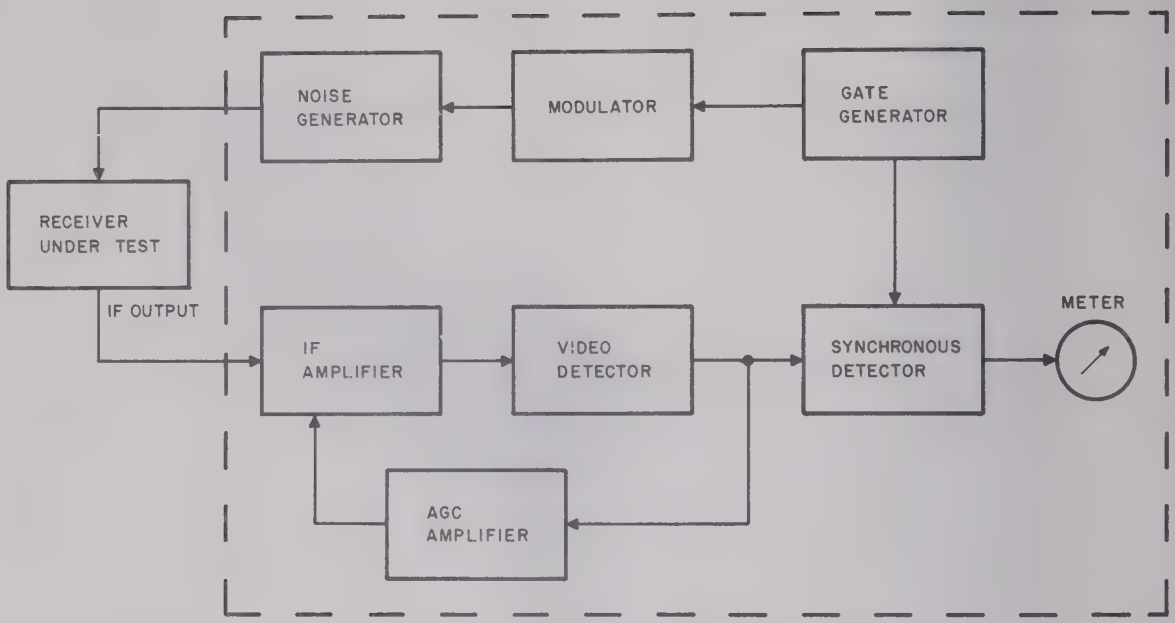


FIGURE 14. BLOCK DIAGRAM OF AUTOMATIC NOISE FIGURE INDICATOR

The square-wave output of the detector can be represented as two alternating voltage levels,

$$V_2 = \sqrt{KN_{o2}} \tag{6-12}$$

$$V_1 = \sqrt{KN_{o1}} \tag{6-13}$$

where N_{o2} and N_{o1} are the noise output powers of the receiver under test with the noise generator on and off respectively, K is a proportionality constant that takes into account IF gain and the detector characteristics. The average of these two voltages can be written

$$V_{avg} = V_1 + \frac{V_2 - V_1}{2} \tag{6-14}$$

and the amplitude of the square wave is the difference between them:

$$V_{p-p} = V_2 - V_1 \tag{6-15}$$

Dividing equation 6-15 by equation 6-14,

$$\frac{V_{p\text{-}p}}{V_{avg}} = \frac{V_2 - V_1}{V_1 + \frac{V_2 - V_1}{2}} \tag{6-16}$$

Rearranging,

$$\frac{V_{p\text{-}p}}{V_{avg}} = \frac{1}{\frac{V_1}{V_2 - V_1} + \frac{1}{2}} \tag{6-17}$$

Substituting equation 6-12 and 6-13 into equation 6-17,

$$\frac{V_{p\text{-}p}}{V_{avg}} = \frac{1}{\frac{\sqrt{KN}_{o1}}{\sqrt{KN}_{o2} - \sqrt{KN}_{o1}} + \frac{1}{2}} \tag{6-18}$$

Rearranging and eliminating K,

$$\frac{V_{p\text{-}p}}{V_{avg}} = \frac{1}{\frac{1}{\sqrt{\frac{N_{o2}}{N_{o1}} - 1}} + \frac{1}{2}} \tag{6-19}$$

The ratio N_{o2}/N_{o1} is, of course, the Y factor, and from equation 6-8,

$$Y = \frac{T_{ex}}{F} + 1 \tag{6-20}$$

Substituting into equation 6-19,

$$\frac{V_{p\text{-}p}}{V_{avg}} = \frac{1}{\frac{1}{\sqrt{\frac{T_{ex}}{F} + 1 - 1}} + \frac{1}{2}} \tag{6-21}$$

Equation 6-21 shows that, since V_{avg} is held constant by AGC action, and T_{ex} is a known constant, the peak-to-peak output of the detector is a measure of the receiver noise figure.

B. CIRCUIT FUNCTIONS

1. GENERAL

The ANFI is designed to accept noise signals and, from these, compute the noise figure of the system under test. Figure 15 is a block diagram of the ANFI with the controls set for the automatic measurement of noise figures using a gas-discharge type noise generator. Multifunction circuits are described in the following paragraphs. Figure 16 is a schematic diagram of the ANFI.

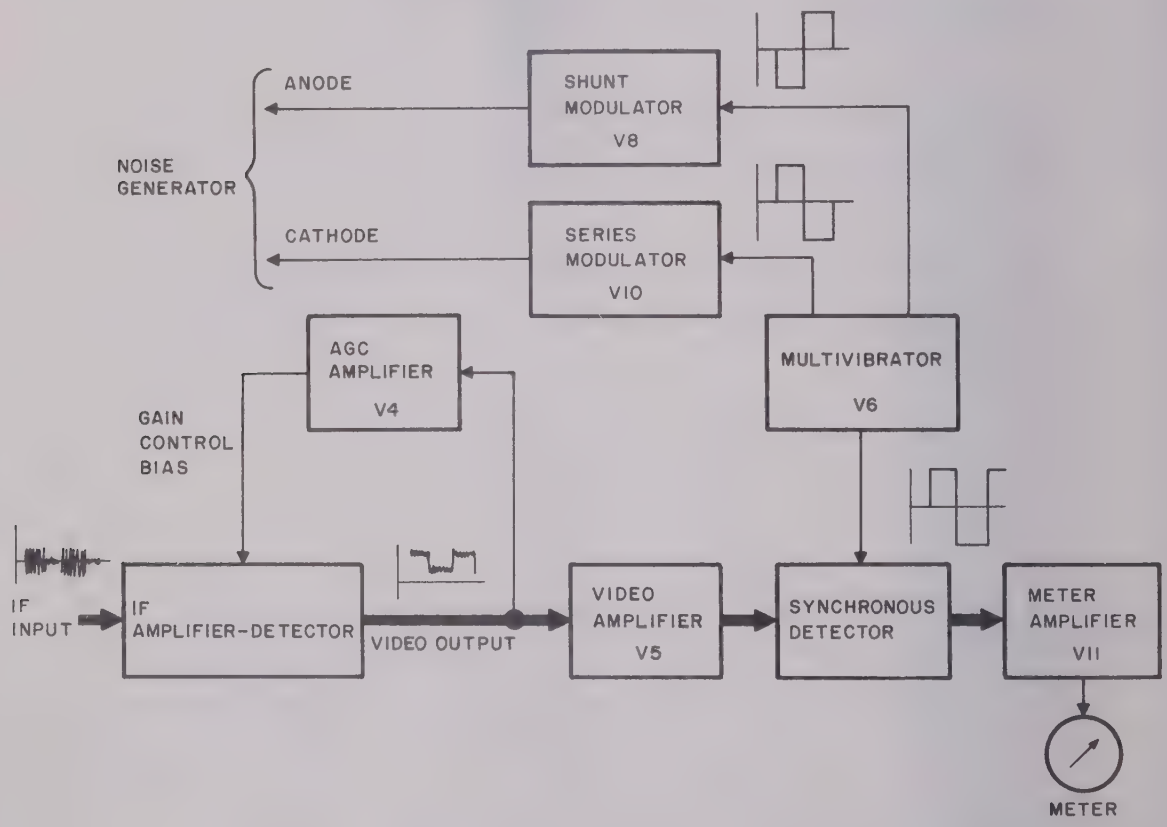


FIGURE 15. BLOCK DIAGRAM OF ANFI WITH CONTROLS SET FOR AUTOMATIC MEASUREMENT OF NOISE FIGURE

The square-wave-modulated, 30-Mc noise signals are amplified and detected in the modular IF amplifier. The detected noise signals are then simultaneously applied to the AGC amplifier and the video amplifier. The AGC amplifier integrates the video signal and develops a DC voltage proportional to the average level of the detector output. This voltage is then applied to the control grids of several IF stages, resulting in a constant average detector output. The video amplifier raises the level of the detected signal, and its output is applied to the synchronous detector. The video amplifier also contains a compensated video attenuator that is switched in for measurement of low noise figures. This eases the linearity requirements of both the synchronous detector and the second half of the video amplifier by restricting the signal level range. The output of the synchronous detector (actually a synchronous, full-wave, bidirectional switch) is a DC voltage proportional to the difference between the levels of the detector square-wave output. As noted earlier, this voltage is a function of receiver noise figure. This output is applied to a differential DC amplifier and then to the front-panel meter. The modulation signal used to fire the noise generator and the switching signal for the synchronous detector are derived from a free-running, plate-coupled multivibrator. The ignition spike, a high-voltage pulse that starts the ionization process within the noise generator, is derived from the shunt modulator; the ionization process is stopped by the series modulator.

2. VIDEO AMPLIFIER

The detected signal is applied to video amplifier V5 through coupling capacitor C7. The two halves of the tube are arranged as a two-stage, cascaded, RC-coupled amplifier. When the METER INDICATION-NF RANGE-DB 0-25 button is pressed, the output of the first stage is coupled to the second-stage grid through a compensated video attenuator made up of C9, R67, and R68. When the METER INDICATION-NF RANGE-DB 23-36 button is pressed, this attenuator is bypassed and the signal is fed directly into the grid of the second stage. The purpose of this attenuator is to reduce the amplitude of the signals resulting from low noise figure measurements. It should be remembered that the peak-to-peak output of the detector is an inverse function of noise figure: the lower the noise figure, the greater the signal level. This simplifies the amplifier circuitry in that the same fixed-gain video amplifier can be used for both high and low noise figure measurements without unusually stringent linearity requirements.

3. SYNCHRONOUS DETECTOR

The output of the video amplifier is applied to the synchronous detector. This circuit provides a DC voltage proportional to the peak-to-peak output of the video amplifier. T3 is an audio transformer whose primary is driven by the same square-wave signal that controls the noise generator. The output of the secondary, therefore, is phase-coherent with the video amplifier output. The primary is connected so that the upper end of the secondary (terminal 12) is positive during the "on" time of the noise source (gas-discharge-type noise generator only). The relative signal levels are such that the switching signal (that applied to the primary) is an order of magnitude greater than the video signal. When terminal 12 is driven positive, and hence terminal 7 negative, CR2 and CR4 conduct heavily while CR1 and CR3 are cut off. C11 can now charge to the peak value of the square-wave input signal. When the driving signal reverses phase on the other half-cycle, CR2 and CR4 cut off and CR1 and CR3 conduct heavily. The input signal reverses phase at the same time and the signal is now clamped to ground. The effect is that when the signal and the driving voltage again go positive, C11 charges to the full peak-to-peak voltage of the input signal.

4. DIFFERENTIAL CATHODE FOLLOWER

The output of the synchronous detector is applied to one side of the differential DC cathode follower made up of V11 and its associated circuitry. When noise figure measurements are being made, the switching circuitry effectively connects the front panel meter between the junction of R70 and R48 and the center arm of potentiometer R40. R40, which can be adjusted with a screwdriver through a hole in the front panel, provides for dynamic balancing of the differential cathode follower at zero input signal (that is, infinite noise figure). The switching circuitry also provides for two separate dropping resistors in series with the meter. This permits individual calibration on each of the two noise figure ranges. When a signal is applied to the input grid of V11, an unbalance occurs across the two cathodes, causing a current to flow through the meter. This current is proportional to the applied DC voltage. Therefore, the meter provides an indication related to the noise figure of the system under test.

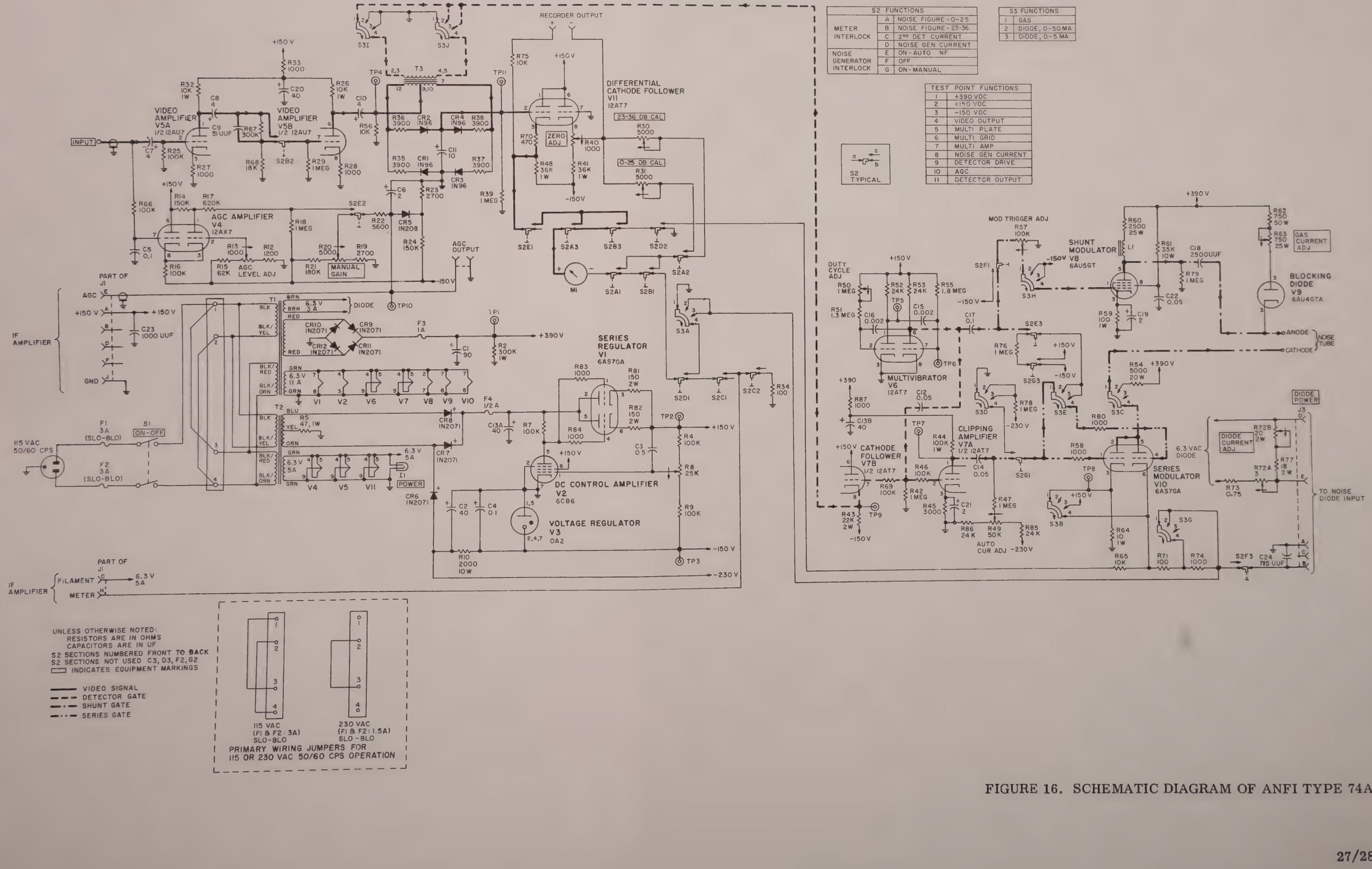


FIGURE 16. SCHEMATIC DIAGRAM OF ANFI TYPE 74A

5. MULTIVIBRATOR

V6 is connected as a standard, free-running, plate-coupled multivibrator. This circuit provides all of the gating and timing waveforms required by the noise figure indicator. Variable resistor R50 located in the grid return of one side of the multivibrator, provides a precise adjustment of square-wave symmetry.

6. CLIPPING AMPLIFIER AND CATHODE FOLLOWER

The output of the multivibrator is applied simultaneously to both grids of V7. One-half of this tube is connected as a cathode follower. Its output provides the switching signal for the synchronous detector. The other half of the tube is a clipper amplifier. Its output, an amplified square wave, provides the driving signal for the series modulator.

7. SHUNT MODULATOR

The shunt modulator is made up of V8, V9, and their associated circuitry. V8 is normally biased in its linear region, and its plate current is drawn through high-inductance choke L1. When the multivibrator output goes negative, V8 is suddenly cut off and the current through L1 is interrupted. The energy stored in the magnetic field of this inductor gives rise to a large positive voltage at pin 5 of the tube. This waveform is coupled through C18 to the anode of the gas-discharge noise generator and causes ionization of the gas molecules within the tube. Sustaining voltage to maintain the gas-discharge noise generator in the fired condition is applied through R62, R63, and V9. V9 is a decoupling diode that prevents the high-voltage pulse at the output of V8 from getting back into the sustaining voltage power supply. R63 provides for an adjustment of the current through the gas-discharge noise generator.

8. SERIES MODULATOR

Both halves of V10, wired in parallel, are connected in series with the cathode of the gas-discharge noise generator. This tube acts as a switch that closes during the desired "on" time, permitting current to be drawn through the gas-discharge noise generator, and opens during the desired "off" time, interrupting the current through the gas-discharge noise generator. V10 is driven by the output of the modulator driver (V7). Just before the application of

the high-voltage pulse at the output of the shunt modulator, V10 is held cut off. At the time that the pulse is applied, the driving waveform goes highly positive, permitting V10 to draw current. At the end of the desired "on" time, the driving waveform again cuts off V10 and interrupts the current through the gas-discharge noise generator, causing it to de-ionize.

9. AGC AMPLIFIER

The output of the video detector in the IF amplifier assembly is applied to the integrator made up of R66 and C5. The time constant of this integrator is long in comparison with the period of the modulating signal. The voltage across C5, therefore, is a DC voltage proportional to the average level of the rectified signal. This is applied to one grid of V4, a cathode-coupled DC amplifier. When making automatic measurements, the output of V4 is applied to the grid control decoupling chain in the IF amplifier assembly through R22. CR5 is a protective device that prevents the DC grid voltage on the gain-controlled tubes from becoming more positive than about -1.8 volts. R13, in the grid circuit of one side of the DC amplifier, sets the output IF level. When manual measurements are being made, the pushbutton switch circuitry disconnects the output of V4, and gain control is obtained by means of R20 mounted on the front panel.

10. POWER SUPPLIES

Four distinct power supplies are required for operation of the Automatic Noise Figure Indicator circuitry. Unregulated high voltage of about +390 volts is required for operation of the modulator and the gas-discharge noise generator. This is derived from the bridge rectifier made up of CR9 through CR12, driven by the high-voltage secondary of T1. R2 is a bleeder that discharges filter capacitor C1 when the unit is de-energized. A fuse is inserted in this supply line for protection of the rectifier diodes. Regulated +150 volts is required for the IF and metering circuitry. This is derived from the regulator made up of V1 and V2 and their associated components. V1 is a series regulator, and V2 is a shunt control tube. Reference voltage for this regulator is derived from a third supply, a -150 volt regulator. Unregulated supply voltage for the +150 volt regulator is provided by the full-wave center-tap rectifier made up of CR7, CR8, and T2. This line is also fused. The reference voltage, -150 volts, for the +150 volt regulator and bias voltage for the IF and metering circuitry are derived from the half-wave rectifier

(CR6) and gas tube regulator (V3). An unregulated -230 volts is tapped off in front of R10 and is used as a bias supply for the series modulator. A filament supply is provided for operation of an external thermionic noise diode. Filament current control is provided by R72A and R72B. Since the noise diode is operated in a temperature-limited condition, this control will vary its DC plate current.

11. MANUAL OPERATION, GAS-DISCHARGE NOISE GENERATOR

The switching circuitry of the ANFI provides for firing and extinguishing of the gas-discharge noise generator manually to make manual Y-factor measurements. When the NOISE GENERATOR-MANUAL-OFF button is pressed, the pulse line to the shunt modulator is opened. This prevents the noise generator from firing after the series modulator de-ionizes the tube by interrupting the current in the next half-cycle. When the NOISE GENERATOR-MANUAL-ON button is pressed, the 400-cycle signal is again applied to the shunt modulator. However, the series modulator grid is grounded, permitting the noise generator to draw current continuously.

12. THERMIONIC NOISE DIODE OPERATION

The ANFI is capable of operating a thermionic noise diode in all of the modes indicated above for a gas-discharge noise generator. This feature is provided by a front-panel rotary switch in conjunction with the pushbutton switch bank. In addition, the noise diode can also be operated in a very low current condition for making manual 3-db measurements (constant Y factor). When the ANFI is set for noise diode operation, the shunt modulator is inoperative. The series modulator operates in essentially the same manner as for the gas-discharge noise generator, except that it is used as a plate current switch.

VII. MAINTENANCE

A. ADJUSTMENTS

1. AUTOMATIC GAIN CONTROL ADJUSTMENT

The calibration of the automatic indication circuits of the ANFI is dependent upon a constant average second detector output during the measurement. In addition, the actual scaling of the meter depends upon a knowledge of this average level. To set the AGC level, proceed as follows:

a. Apply a 100-microvolt signal at intermediate frequency directly into IF input.

b. Press NOISE GENERATOR-AUTO NF-ON button.

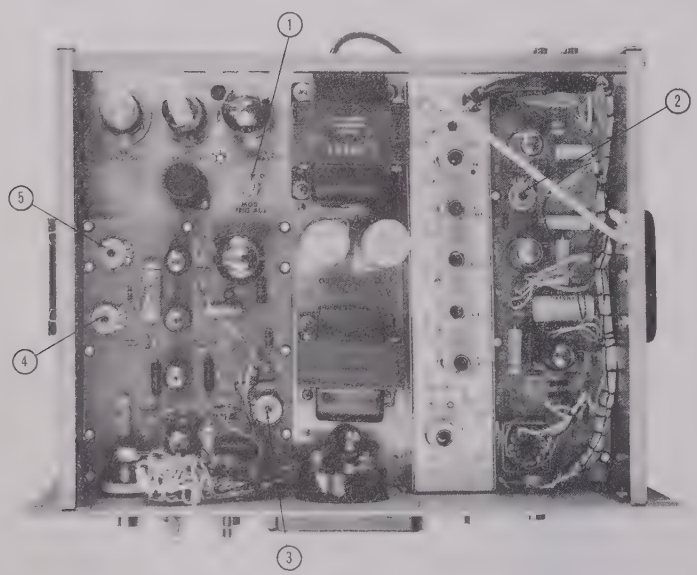
c. Press METER INDICATION-CURRENT-2ND DET button.

d. Adjust AGC Level Adjust R13 for exactly 0.5 ma of second detector current.

e. Reduce signal level until 2ND DET indication on meter falls to 480 microamperes. Signal generator output should be less than 50 microvolts (sensitivity of 30-Mc amplifier).

f. Increase signal generator output 65 db. Meter indication should not move more than two small divisions from full scale.

g. If above condition is not met, adjust AGC Level Adjust R13 (see Figure 17) for full-scale deflection of meter.



1. R57 MOD TRIGGER ADJUST
2. R13 AGC LEVEL ADJUST
3. R49 AUTO CURRENT ADJUST
4. R50 DUTY CYCLE ADJUST
5. R8 DC LEVEL ADJUST

FIGURE 17. INTERNAL ADJUSTMENTS

2. AUTOMATIC CURRENT ADJUSTMENT

This adjustment ensures that the noise generator is operating properly during an automatic measurement.

a. GAS-DISCHARGE NOISE GENERATOR

(1) Set up equipment as shown in Figure 4.

(2) Press NOISE GENERATOR-MANUAL-ON button.

(3) Press METER INDICATION-CURRENT-NOISE GEN button.

(4) Set GAS-CURRENT ADJ. control for proper current for noise generator being used.

(5) Press NOISE GENERATOR-AUTO NF-ON button.

(6) Adjust Auto Current Adjust R49 (see Figure 17) for a meter indication within 3 percent of one-half the current set in step (4).

b. DIODE NOISE GENERATOR

(1) Perform an automatic noise figure measurement as described in paragraph V-B.

(2) Adjust Auto Current Adjust R49 (see Figure 17) for a minimum noise figure reading on the meter.

3. MODULATOR TRIGGER ADJUSTMENT

a. Set up equipment as shown in Figure 4.

b. Press NOISE GENERATOR-MANUAL-OFF button.

c. Turn MOD TRIG ADJ. R57 (see Figure 17) fully counterclockwise.

d. Press NOISE GENERATOR-MANUAL-ON button.

e. Turn R57 clockwise until meter indicates that noise generator is firing; then turn it just slightly beyond this point.

f. Adjust GAS-CURRENT ADJ. control for proper current for noise generator being used.

g. Press NOISE GENERATOR-AUTO NF-ON button. Observe meter indication for any evidence of instability or misfiring. If misfiring is indicated, continue turning R57 clockwise until instability disappears.

h. Repeat procedure described in paragraph VII-A-2.

4. AUTOMATIC NOISE FIGURE CALIBRATION

a. 0 - 25 DB RANGE

(1) Make a manual noise figure measurement as described in paragraph V-C.

NOTE

For the purpose of calibrating the ANFI, noise figure must be computed from a manual Y-factor measurement on the basis of T_{ex} = 15.3 db.

(2) Make an automatic noise figure measurement as described in paragraph V-A or V-B.

(3) Compare figures obtained in steps (1) and (2). They should agree. If they do not agree, proceed to step (4).

(4) With equipment set up for an automatic noise figure measurement, disconnect input to IF amplifier of ANFI.

(5) Press METER INDICATION-NF RANGE-DB 23 - 36 button.

(6) Turn ZERO ADJ. control for a meter indication of infinite noise figure.

(7) Connect IF input to IF amplifier of ANFI.

(8) Press METER INDICATION-NF RANGE-DB 0 - 25 button.

(9) Adjust 0 - 25 DB CAL control until automatic indication agrees with manual measurement.

b. 23 - 36 DB RANGE

The 23 - 36 db range is calibrated in a manner similar to that used for the 0 - 25 db range. Use a test device with a noise figure greater than 23 db. If a device with a high noise figure is not available, it can be simulated by inserting enough attenuation between the noise generator and the equipment under test to sufficiently degrade the noise figure. The amount of noise figure degradation is exactly equal to the attenuation inserted.

5. MULTIVIBRATOR DUTY CYCLE ADJUSTMENT

a. Check the multivibrator duty cycle as described in paragraph VII-B-6.

b. Adjust Duty Cycle Adjustment R50 until the waveform at TP5 is an approximate square wave, 90 volts peak to peak, with a 40-volt negative overshoot, and a 50-percent duty cycle.

B. TROUBLESHOOTING

1. POWER SUPPLIES

a. GENERAL

(1) Check fuses F1 and F2 at rear of chassis. If they show continuity, proceed to paragraph 6, following.

(2) If F1 and F2 are blown, check components preceding fuses F3 and F4 for a short circuit. Check condition of rectifier diodes.

(3) Check C2. If C2 is short-circuited, check CR6 carefully. A failure in C2 usually causes a failure in CR6.

b. +390 VOLT SUPPLY

This unregulated power supply provides the sustaining voltage for the gas-discharge noise generator and B+ for shunt modulator V8 and clipping amplifier V7A. Since the supply is unregulated, the output voltage will be a function of the load on the supply at the time of measurement.

(1) Press NOISE GENERATOR-MANUAL-OFF button, and check for about 405 volts at junction of C1 and R2.

(2) If no voltage is present, check condition of F3, the series B+ fuse for this supply. If F3 is open-circuited, check filter capacitor C1 for a short circuit.

(3) With gas-discharge noise generator connected and current adjusted to about 200 ma, press NOISE GENERATOR-MANUAL-ON button. Voltage should not drop below 375 volts.

(4) If voltage drops to an extremely low value when ON button is pressed, check noise generator current by pressing METER INDICATION-CURRENT-NOISE GEN button. If current is unstable and very low, replace noise generator and carefully check condition of series modulator V10.

(5) If voltage is low regardless of which button is pressed, check four bridge rectifier diodes CR9 through CR12 for an open circuit.

c. +150 VOLT SUPPLY

This is an electronically regulated power supply that provides B+ for the IF amplifier and the remainder of the control circuitry. The line from the center-tapped rectifier diodes to the regulator is fused by F4.

(1) Check F4. Its failure indicates an excessive current drain on rectifier portion of power supply.

(2) If F4 has failed, check carefully for a short circuit in filter capacitor C13. Normally, voltage across C13 (input voltage to the regulator) will be about 220 volts DC and load current will not exceed 100 ma.

(3) To check load current, measure voltage drop across R81 and R82 in cathodes of series regulator V1.

(4) To check regulator output, monitor voltage at TP2.

(5) If regulator input voltage is low, check CR7 and CR8 for open.

(6) If input voltage is normal and output voltage is low, this indicates an unusually heavy load on regulator that is not quite enough to cause F4 to fail. Locate faulty component by selectively disconnecting each load within ANFI.

(7) If voltage at TP2 is very high (over 160 volts), proceed to paragraph d following, and check -150 volt power supply.

(8) R8, 25-kilohm potentiometer provides a means for setting output voltage of this supply to precisely +150 volts. To determine regulation characteristics of the power supply, connect an oscilloscope or AC VTVM between TP2 and ground and a variable autotransformer in the input AC line. The high and low line voltages at which the circuit drops out of regulation will be indicated by a sudden jump in ripple voltage value measured at TP2. With NOISE GENERATOR - MANUAL - OFF button pressed, the normal ripple voltage is about 300 mv peak to peak. The supply should regulate to within $\pm$1.5 volts over an input range of 105 to 128 volts.

d. NEGATIVE POWER SUPPLIES

Two negative voltages are obtained from half-wave rectifier CR6 -- an unregulated -230 volts and a regulated -150 volts. The -230 volt output is obtained directly from the output of CR6 and is filtered by C2. The -150 volt output is obtained at TP3 and is regulated at $\pm$2 volts over the nominal operating potential of V3, which is 145 to 155 volts. To troubleshoot the negative supplies, proceed as follows:

(1) A loss of unregulated -230 volts is usually accompanied by blown line fuses. Follow troubleshooting procedure in paragraph B-1-a.

(2) A malfunction in -150 volt regulated supply will affect regulated +150 volt supply. Almost every type of malfunction in this circuit will cause main line fuses to blow. Therefore, check F1 and F2.

2. IF GAIN CONTROL CIRCUITS

IF amplifier gain is automatically controlled by the AGC amplifier (V4) when the NOISE GENERATOR - AUTO NF - ON button is pressed. When either NOISE GENERATOR - MANUAL button is pressed, gain is a function of the MANUAL GAIN control. A malfunction in V4 is usually indicated by a wide variation in the automatic indication of noise figure as the signal level at the input to the ANFI is varied. To troubleshoot this circuit, a signal generator capable of providing a calibrated output at the intermediate frequency of the ANFI is required, and the IF amplifier must be operating properly. To indicate noise figure correctly, the AGC amplifier must maintain the average second detector output of the IF amplifier at 0.5 ma.

a. TROUBLESHOOTING AUTOMATIC GAIN CONTROL CIRCUIT

(1) Adjust the automatic gain control for proper operation as described in Section VII-A.

(2) If circuit does not perform properly, malfunction is associated with V4.

(3) AGC voltage applied to IF amplifier can be monitored with a high-impedance VTVM connected to binding post at rear of ANFI chassis (marked AGC OUTPUT). AGC voltage should vary inversely as the signal voltage--it should become more negative as input signal level is increased.

b. TROUBLESHOOTING MANUAL GAIN CONTROL CIRCUIT

To make an overall check of the manual gain control circuit and the remainder of the AGC circuit, proceed as follows:

(1) Disconnect IF input to ANFI.

(2) Press NOISE GENERATOR - MANUAL - OFF button.

(3) Turn MANUAL GAIN control fully counterclockwise (maximum gain).

(4) Measure voltage at AGC output. It should not be more positive than about -1.6 volts. In addition, it should vary smoothly with setting of MANUAL GAIN control.

(5) If voltage variation indicates that both manual and automatic gain control circuits are operating properly but second detector current does not remain constant as input is varied (when on automatic operation), carefully check operation of IF amplifier. (See appropriate IF Amplifier Appendix.)

3. VIDEO AMPLIFIER

The video amplifier is made up of both halves of V5. The signal is applied to the grid of the second stage through a compensated video attenuator that can be switched out of the circuit when the high range METER INDICATION - NF RANGE-DB button is pressed. A loss of gain through this amplifier would be indicated by the inability to properly calibrate the instrument in the automatic mode. A failure of the tube or one of its components would be indicated by a continuous reading of infinite noise figure. The output of the video amplifier can be observed at TP4. The peak-to-peak amplitude of the signal at this point will, of course, depend upon the noise figure of the system under test. However, for a good low-noise device, the video signal observed by an oscilloscope will be about 1 volt peak to peak.

4. SYNCHRONOUS DETECTOR

The synchronous detector is a full-wave bidirectional switch driven from the same square-wave source that operates the modulator and, hence, the noise source. A malfunction within the detector will produce the same results as one in the video amplifier --that is, a loss of signal will cause the noise figure indication to be very high or, with a complete loss of signal, infinite. To trouble-shoot this circuit, proceed as follows:

a. Observe waveform at TP9 to determine whether or not gating signal is being applied to synchronous detector. It should be a square wave of about 10 volts peak-to-peak amplitude.

b. If gating signal is present and it has been determined that video amplifier is operating properly, check diodes CR1 through CR4.

c. Check integrating capacitor C11.

5. DIFFERENTIAL CATHODE FOLLOWER

The DC output of the synchronous detector is compared, in the cathode circuit, with a reference voltage determined by a setting of R40, the ZERO ADJ. control. One end of front-panel meter M1 is connected to the reference, the center arm of R40; the other, to the output of the second half of the differential cathode follower. A complete failure of any component within this circuit will produce the same results as a signal loss anywhere within the signal chain from the IF ampli-

fier input through the synchronous detector output. A more serious malfunction occurs when the tube has degraded to the point where the DC current through either half drifts rapidly with time. This condition is indicated when the zero (that is, the indication of infinite noise figure) drifts rapidly. To obtain the zero indication, proceed as follows:

a. Press either METER INDICATION - NF RANGE - DB button.

b. Press NOISE GENERATOR - AUTO NF - ON button.

c. Disconnect input to IF amplifier.

d. Meter should read infinite noise figure. If it does not, adjust R40, by inserting a screwdriver through front panel, until proper indication is obtained.

e. If meter indication tends to drift rapidly about this point, change V11.

6. MULTIVIBRATOR

The multivibrator V6 is the prime source of all gating and synchronizing signals within the ANFI. A failure within this circuit will result in a lack of any indication of automatic noise figure. In addition, should the multivibrator fail to operate, a gas-discharge noise lamp connected to the noise generator terminals will not ignite. To check the operation of the multivibrator, proceed as follows:

a. Observe waveform at TP5 with an oscilloscope.

CAUTION

Because the impedance levels within this circuit are relatively high, connect the oscilloscope by means of a high-impedance, low-capacitance probe.

b. When checking waveform: gas-discharge noise generator should be connected, NOISE GENERATOR - AUTO NF - ON button should be pressed, and noise generator should be adjusted for correct current.

c. Waveform at TP5 should be an approximate square wave, 90 volts peak to peak, with about a 40-volt negative overshoot. Square wave should have a 50-percent duty cycle.

d. If necessary, adjust duty cycle of multivibrator as described in paragraph VII-A-5.

7. CLIPPING AMPLIFIER AND CATHODE FOLLOWER

One-half of V7 is used as a cathode-follower clipper and provides the gating signal for the synchronous detector. This circuit can be checked by observing the waveform at TP9 with an oscilloscope. It should be a square wave of about 10 volts peak-to-peak amplitude, with a slight overshoot on both the positive and negative halves. The second half of V7 is used as a clipping amplifier and provides the driving waveform for the series modulator. Clipping is accomplished by overdriving the tube in both the positive and negative directions and by the action of the series grid resistor R46. A failure within this circuit will prevent the noise generator from firing in the automatic mode. The output waveform of the amplifier can be observed at TP7 with an oscilloscope. It should be a square wave with about a 220 volt peak-to-peak amplitude.

8. SHUNT MODULATOR

V8 and its associated circuitry provides the firing spike that initiates the ionization within the gas-discharge noise generator. A failure within this circuit will prevent the noise generator from firing in either the manual or the automatic mode. R57 can be adjusted to set the amplitude of the firing spike at the minimum level required to trigger the tube into the "on" condition. The circuit can be checked by holding an oscilloscope probe near the envelope of V8 or near its socket on the underside of the chassis. The procedure for adjusting R57 is given in VII-A-3.

CAUTION

Do not attempt to connect an oscilloscope directly to the plate of this tube since the peak voltages at pin 5 can be as high as 4.5 kv.

9. SERIES MODULATOR

All malfunctions within V10 will prevent normal operation of the noise generator. The circuit can be checked by observing waveform at TP8; this is the current waveform of the noise generator. The signal is characterized as a square wave of about 2.5 volts peak to peak. The actual value will, of course, depend upon the setting of the noise generator current. The positive half of the square wave will contain a considerable amount of ripple. In addition, depending upon the noise

generator used, it may also contain several small negative spikes. If the circuit is operating properly, the negative slope of the square wave will drop sharply to zero when the noise generator is switched off. If the negative-going portion of the signal drops slowly with a long decay time, then V10 should be changed--this is usually an indication of a gassy tube. The bias setting on the grids of V10 determines the average value of the noise generator current in the automatic mode. R49 provides an adjustment for this bias. The procedure for setting this control is given in VII-A-2.

10. IF AMPLIFIER

The alignment and adjustment of the IF amplifier is extremely critical to the operation of the ANFI, therefore, do not attempt realignment of the IF amplifier unless it has been conclusively determined that a malfunction or misalignment actually exists within the unit. The alignment procedures for the IF amplifiers that are available for use with the ANFI are provided in the appendices to this handbook.

C. REPLACEABLE PARTS LIST

Reference Symbol	Description	Manufacturer	Part No.
C1	Capacitor, electrolytic, 90 μf, 500 v	Sprague	TVL-1960
C2	Capacitor, electrolytic, 40 μf, 450 v	Sprague	TVL-1725
C3	Capacitor, Mylar, tubular, 0.50 μf, 200 v	Cornell-Dubilier	PM2P5
C4, 5, 17	Capacitor, Mylar, tubular, 0.10 μf, 200 v	Cornell-Dubilier	PM2P1
C6, 19, 21	Capacitor, electrolytic, 2.0 μf, 50 v	Aerovox	Type SRE
C7, 8, 10	Capacitor, electrolytic, 4.0 μf, 150 v	Sprague	TVA-1402
C9	Capacitor, Dur-Mica, 51 pf, 500 v	Arco Electronics	DM-15
C11	Capacitor, electrolytic, 50 μf, 25 v	Cornell-Dubilier	BBR-50-25

Reference Symbol	Description	Manufacturer	Part No.
C12	Capacitor, molded, tubular, 0.05 μf, 200 v	Sprague	2TM-S50
C13	Capacitor, electrolytic, 40 - 40 μf, 450 v	Sprague	TVL-2764
C14, 22	Capacitor, molded, tubular, 0.05 μf, 600 v	Sprague	6TM-S50
C15, 16	Capacitor, molded, tubular, 0.002 μf, 600 v	Sprague	6TM-D20
C18	Capacitor, disk, ceramic, 2500 pf, 3000 v	Centralab	DD30-252
C20	Capacitor, electrolytic, 40 μf, 150 v	Sprague	TVA-1413
C23	Capacitor, ceramic, 1000 pf 1000 v	Centralab	DD102
C24	Capacitor, ceramic, 715 pf 500 v	Erie	331
CR1, 2, 3, 4	Diode, germanium	Hughes	1N96
CR5	Diode, silicon	Hoffman	1N208
CR6, 7, 8, 9, 10, 11, 12	Rectifier, diffused silicon	Texas Instruments	1N2071
F1, 2	Fuse, cartridge, time lag, 3 amp, 125 v	Bussmann	MDX-3
F3	Fuse, cartridge, 1 amp, 250 v	Bussmann	AGC-1
F4	Fuse, cartridge, $\frac{1}{2}$ amp, 250 v	Bussmann	AGC-$\frac{1}{2}$
I1	Pilot light assembly	Dialight	52410-991
J1	Connector, locking-clip type	Amphenol	126-222
J2	Connector, coaxial, BNC	Amphenol	UG88/U
J3	Connector, miniature type AN	Amphenol	165-36
L1	Choke	Merit	C-2991
M1	Meter	AIL	113592
R2	Resistor, fixed, 300 k, 1 w		RC32GF304J
R4, 7, 9, 16, 25, 46, 66, 69	Resistor, fixed, 100 k, $\frac{1}{2}$ w		RC20GF104J
R5	Resistor, fixed, 47 ohms, 1 w		RC32GF470J
R8	Resistor, variable, 25 k, $\frac{1}{2}$ w	Stackpole	Type LH61

Reference Symbol	Description	Manufacturer	Part No.
R10	Resistor, fixed-ceramic, 2 k, 10 w	AIL	205482-1
R12	Resistor, fixed, 1.2 k, ½ w		RC20GF122J
R13	Resistor, variable, 1000 ohms, ½ w	Stackpole	Type LH61
R14, 24	Resistor, fixed, 150 k, ½ w		RC20GF154J
R15	Resistor, fixed, 62 k, ½ w		RC20GF623J
R17	Resistor, fixed, 620 k, ½ w		RC20GF624J
R18, 29, 39, 42, 47, 76, 78	Resistor, fixed, 1 meg, ½ w		RC20GF105J
R19	Resistor, fixed, 2.7 k, ½ w		RC20GF272J
R20	Resistor, variable, 5000 ohms, 2 w	AIL	115289-9
R21	Resistor, fixed, 180 k, ½ w		RC20GF184J
R22	Resistor, fixed, 5.6 k, ½ w		RC20GF562J
R23	Resistor, fixed, 2.7 k, ½ w		RC20GF272J
R26, 32	Resistor, fixed, 10 k, 1 w		RC32GF103J
R27, 28, 33, 58, 80, 83, 84	Resistor, fixed, 1 k, ½ w		RC20GF102J
R30, 31	Resistor, variable, 5000 ohms, 2 w	AIL	115289-6
R34	Resistor, fixed, 100 ohms, ½ w		RC20GF101J
R35, 36, 37, 38	Resistor, fixed, 3900 ohms, ±1%, ½ w	Corning	Type N 20
R40	Resistor, variable, 1000 ohms, 2 w	AIL	115289-7
R41, 48	Resistor, fixed, 36 k, 1 w		RC32GF363J
R43	Resistor, fixed, 22 k, 2 w		RC42GF223J
R44	Resistor, fixed, 100 k, 1 w		RC32GF104J
R45	Resistor, fixed, 3 k, ½ w		RC20GF302J
R49	Resistor, variable, 50,000 ohms, ½ w	Stackpole	Type LH61
R50	Resistor, variable, 1 meg, ½ w	Stackpole	Type LH61
R51	Resistor, fixed, 1.3 meg, ½ w		RC20GF135J

Reference Symbol	Description	Manufacturer	Part No.
R52, 53	Resistor, fixed, 24 k, $\frac{1}{2}$ w		RC20GF243J
R54	Resistor, fixed, ceramic, 5 k, 20 w	AIL	205483-1
R55	Resistor, fixed, 1.8 meg, $\frac{1}{2}$ w		RC20GF185J
R56, 75	Resistor, fixed, 10 k, $\frac{1}{2}$ w		RC20GF103J
R57	Resistor, variable, 100,000 ohms, 2 w	AIL	116367-5
R59	Resistor, fixed, 100 ohms, 1 w		RC32GF101J
R60	Resistor, fixed, ceramic, 2.5 k, 25 w	AIL	205484-1
R61	Resistor, fixed, ceramic 35 k, 10 w	AIL	205482-2
R62	Resistor, fixed, ceramic, 750 ohms, 50 w	AIL	205485-1
R63	Rheostat, 750 ohms $\pm$10%, 25 w	Ohmite	0157
R64	Resistor, fixed, 10 ohms, 1 w		RC32GF100J
R65	Resistor, precision, 10 k, $\frac{1}{2}$ w	Dale	DCSH-$\frac{1}{2}$
R67	Resistor, fixed, 300 k, $\frac{1}{2}$ w		RC20GF304J
R68	Resistor, fixed, 18 k, $\frac{1}{2}$ w		RC20GF183J
R70	Resistor, fixed, 470 ohms, $\frac{1}{2}$ w		RC20GF471J
R71	Resistor, fixed, 100 ohms $\pm$1%, $\frac{1}{2}$ w	Dale	DCSH-$\frac{1}{2}$
R72	Resistor, variable, dual, 3 ohms and 20 ohms, 2 w	AIL	116713
R73	Resistor, fixed, ceramic, 0.75 ohm, 10 w	AIL	205482-4
R74	Resistor, precision, 1000 ohms $\pm$1%, $\frac{1}{2}$ w	Dale	DCSH-$\frac{1}{2}$
R77	Resistor, fixed, 18 ohms, 2 w		RC42GF180J
R79	Resistor, fixed, 1 meg, $\pm$15%, 1 w, 5000 v	Resistance Prod. Co.	Type BAKW
R81, 82	Resistor, fixed, 150 ohms, 2 w		RC42GF151J
R85, 86	Resistor, fixed, 24 k, $\frac{1}{2}$ w		RC20GF243J
S1	Switch, toggle, dpst	Cutler-Hammer	7590
S2	Switch, pushbutton	AIL	113270

Reference Symbol	Description	Manufacturer	Part No.
S3	Switch, rotary	AIL	118588
T1	Transformer, power	AIL	205559
T2	Transformer, power	AIL	117739
T3	Transformer	UTC	A-20
V1	Tube, electron	Tung-Sol	6080
V2	Tube, electron		6CB6-A
V3	Tube, electron	RCA	OA2
V4	Tube, electron	RCA	12AX7
V5	Tube, electron	RCA	12AU7
V6, 7, 11	Tube, electron	RCA	12AT7
V8	Tube, electron	RCA	6AU5GT
V9	Tube, electron	Tung-Sol	6AU4GTA
V10	Tube, electron		6AS7-G

APPENDIX A

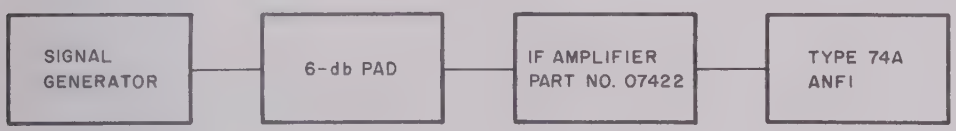
IF AMPLIFIER PART NO. 07422

1. SPECIFICATIONS

Frequency	10 Mc 20 to 60 Mc tunable
Band-Pass Ripple	Negligible
Bandwidth	2 Mc
IF Voltage Gain	35,000
IF Power Gain	69 db
Input Impedance	50 ohms
Load Impedance:	
Video (minimum)	100 k
Second Detector	100 ohms
Video Limiting Voltage	3.5 volts
Gain Control Range	65 db

2. ALIGNMENT PROCEDURE

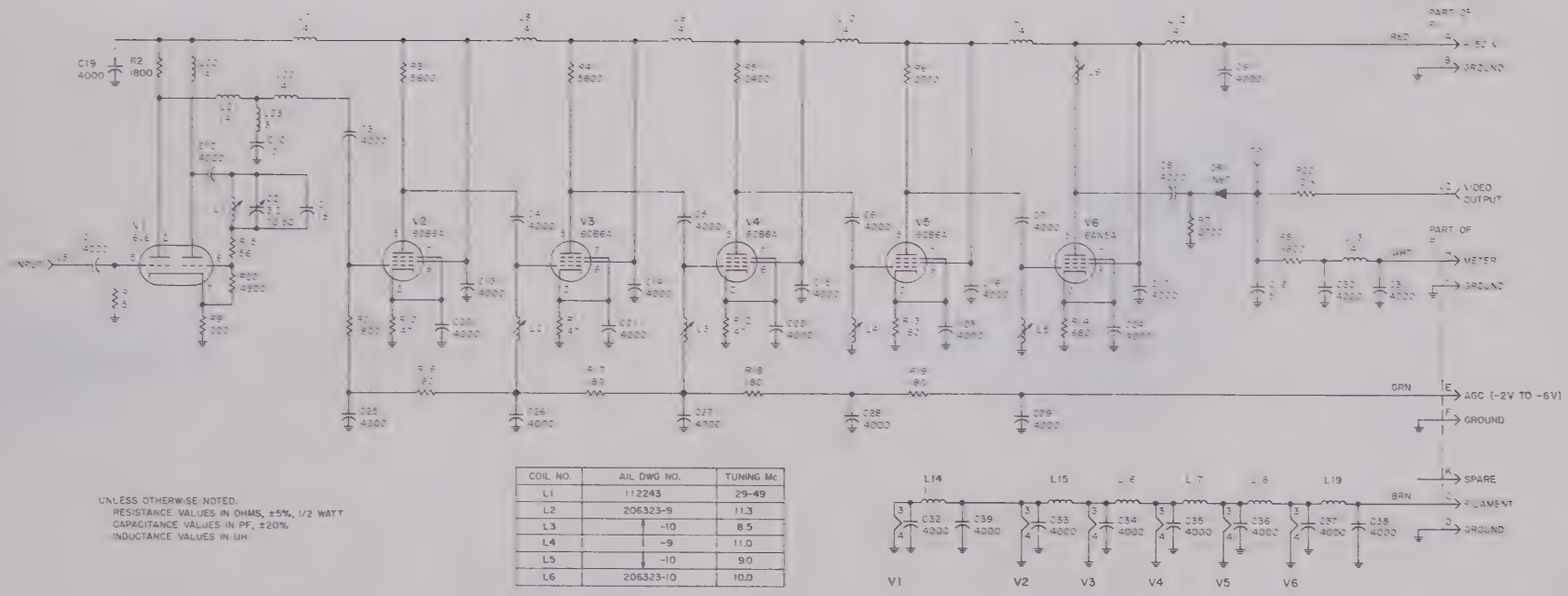
a. Set slugs of L2 and L4 fully out of coil.
b. Set slugs of L3 and L5 fully into coil.
c. Set slug of L6 to approximate center of coil.
d. Set variable capacitor C2 to completely unmeshed position.
e. Connect equipment as shown below.



EQUIPMENT SETUP FOR IF AMPLIFIER 07422 ALIGNMENT

f. Align coils to following frequencies in sequence given. Set MANUAL GAIN control on the Type 74A ANFI to mid-range. Adjust signal generator output so that second detector current on Type 74A ANFI is between 0.2 and 0.5 ma at all times.

Order of Alignment	Coil	Frequency (Mc)
1	L6	10.0
2	L5	9.0
3	L4	11.0
4	L3	8.5
5	L2	11.3



COIL NO.	AIL DWG NO.	TUNING Mc
L1	112243	29-49
L2	206323-9	11.3
L3	-10	8.5
L4	-9	11.0
L5	-10	9.0
L6	206323-10	10.0

UNLESS OTHERWISE NOTED:
RESISTANCE VALUES IN OHMS, ±5%, 1/2 WATT
CAPACITANCE VALUES IN PF, ±20%
INDUCTANCE VALUES IN UH

SCHEMATIC DIAGRAM, IF AMPLIFIER 07422

3. REPLACEABLE PARTS LIST

Reference Symbol	Description	Manufacturer	Part Number
C1,3,4,5,6,7,8,9, 12,13,14,15,16,17, 19,20,21,22,23,24, 25,26,27,28,29,30, 31,32,33,34,35,36, 37,38,39	Capacitor, ceramic, 4000 pf	Centralab	D6-402
C2	Capacitor, trimmer, 3.2-50 pf	Hammer-Lund	MAPC-B50
C10	Capacitor, ceramic, 10 pf	Erie	CC21UJ100J
C11	Capacitor, ceramic, 15 pf	Erie	CC21UJ150J
C18	Capacitor, ceramic, 51 pf	Erie	CC21UJ510J
CR1	Diode, crystal		1N67
L1	Coil, variable	AIL	112243
L2, 4	Coil, variable	AIL	206323-9
L3, 5, 6	Coil, variable	AIL	206323-10
L7,8,9,10,11,12, 13,20,21,22	Inductor, 14 μh	Speers	10102-1
L14,15,16,17,18,19	Inductor, 1.1 μh	Speers	10101-1
L23	Inductor, 3 μh	Speers	10100-2
R1	Resistor, fixed, 51 ohms, 1/2 w		RC20GF510J
R2, 21	Resistor, fixed, 1800 ohms, 1/2 w		RC20GF182J
R3, 4	Resistor, fixed, 5600 ohms, 1/2 w		RC20GF562J
R5	Resistor, fixed, 2400 ohms, 1/2 w		RC20GF242J
R6, 7	Resistor, fixed, 2700 ohms, 1/2 w		RC20GF272J
R8	Resistor, fixed, 6800 ohms, 1/2 w		RC20GF682J
R9	Resistor, fixed, 220 ohms, 1/2 w		RC20GF221J
R10, 11, 12	Resistor, fixed, 47 ohms, 1/2 w		RC20GF470J
R13,16,17,18,19	Resistor, fixed, 180 ohms, 1/2 w		RC20GF181J
R14	Resistor, fixed, 680 ohms, 1/2 w		RC20GF681J
R15	Resistor, fixed, 56 ohms, 1/2 w		RC20GF560J
R20	Resistor, fixed, 4300 ohms, 1/2 w		RC20GF432J
R22	Resistor, fixed, 10 k, 1/2 w		RC20GF103J
V1	Tube, electron		6J6
V2, 3, 4, 5	Tube, electron		6CB6A
V6	Tube, electron		6AN5

APPENDIX B

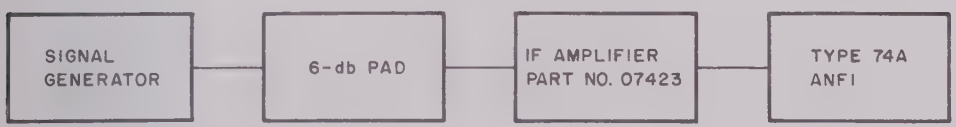
IF AMPLIFIER PART NO. 07423

1. SPECIFICATIONS

Frequency	30 Mc
Band-Pass Ripple	<1 db
Bandwidth	6 Mc
IF Voltage Gain	70,000
IF Power Gain	75 db
Input Impedance	50 ohms
Load Impedance:	
Video (minimum)	100 k
Second Detector	100 ohms
Video Limiting Voltage	3.5 volts
Gain Control Range	65 db

2. ALIGNMENT PROCEDURE

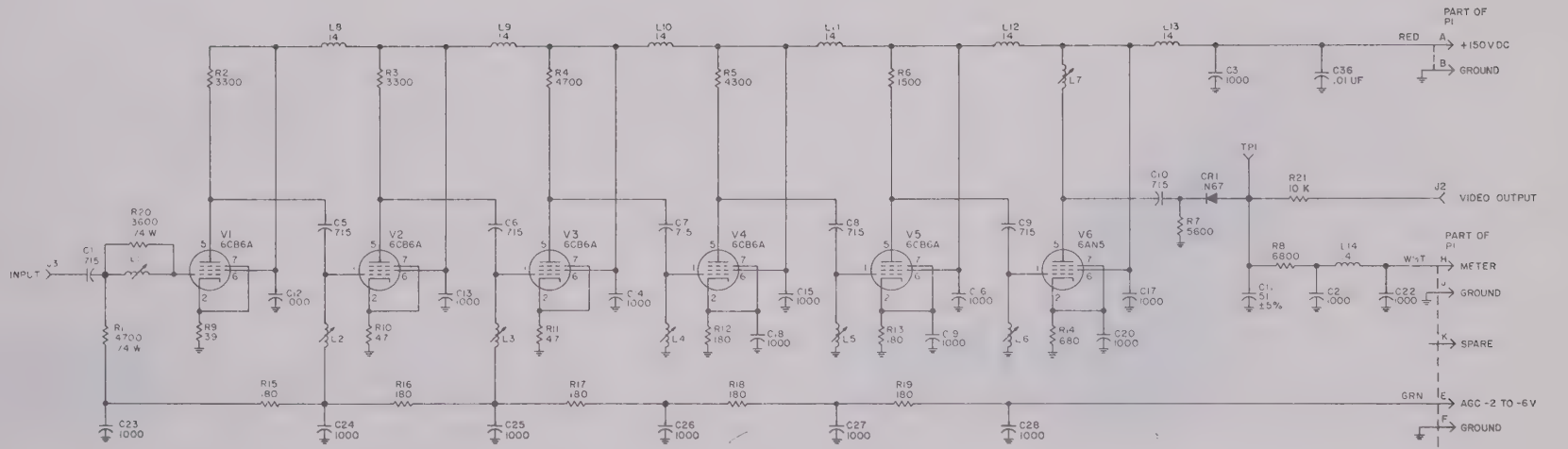
a. Set slugs of L2 and L4 fully out of coil.
b. Set slugs of L3, L5, and L7 fully into coil.
c. Set slugs of L1 and L6 to approximate center of coil.
d. Connect equipment as shown below.



EQUIPMENT SETUP FOR IF AMPLIFIER 07423 ALIGNMENT

f. Align coils to following frequencies in sequence given. Set MANUAL GAIN on Type 74A ANFI to mid-range. Adjust signal generator output so that second detector current on Type 74A ANFI is between 0.2 and 0.5 ma at all times.

Order of Alignment	Coil	Frequency (Mc)
1	L1	29.75
2	L2	33.75
3	L3	26.25
4	L4	33.8
5	L5	26.2
6	L6	31.6
7	L7	28.1



COIL NO	AIL DWG NO	TUNING Mc
L1	112240	29.75
L2	112239	33.75
L3	112240	26.25
L4	112241	33.8
L5	113333	26.2
L6	112239	31.6
L7	114821	28.1

UNLESS OTHERWISE NOTED:
RESISTANCE VALUES IN OHMS, ±5%, 1/2 WATT
CAPACITANCE VALUES IN PF
INDUCTANCE VALUES IN UH

SCHEMATIC DIAGRAM, IF AMPLIFIER 07423

3. REPLACEABLE PARTS LIST

Reference Symbol	Description	Manufacturer	Part Number
C1,5,6,7,8,9,10	Capacitor, ceramic, 715 pf		117212-1
C2, 4, 36	Capacitor, disc, 0.01 pf		115302-1
C3,12,13,14-35	Capacitor, ceramic, 1000 pf		118049-3
C11	Capacitor, ceramic, 51 pf	Erie	CC21UJ510J
CR1	Diode, crystal		1N67
L1, 3	Coil, variable	AIL	112240
L2, 6	Coil, variable	AIL	112239
L4	Coil, variable	AIL	112241
L5	Coil, variable	AIL	113333
L7	Coil, variable	AIL	114821
L8-14	Inductor, molded 14 μh	Speers	10102-1
L15-20	Inductor, molded 1.1 μh	Speers	10101-1
R1	Resistor, fixed, 4700 ohms, 1/4 w		RC07GF472J
R2, 3	Resistor, fixed, 3300 ohms, 1/2 w		RC20GF332J
R4	Resistor, fixed, 4700 ohms, 1/2 w		RC20GF472J
R5	Resistor, fixed, 4300 ohms, 1/2 w		RC20GF432J
R6	Resistor, fixed, 1500 ohms, 1/2 w		RC20GF152J
R7	Resistor, fixed, 5600 ohms, 1/2 w		RC20GF562J
R8	Resistor, fixed, 6800 ohms, 1/2 w		RC20GF682J
R9	Resistor, fixed, 39 ohms, 1/2 w		RC20GF390J
R10, 11	Resistor, fixed, 47 ohms, 1/2 w		RC20GF470J
R12,13,15-19	Resistor, fixed, 180 ohms, 1/2 w		RC20GF181J
R14	Resistor, fixed, 680 ohms, 1/2 w		RC20GF681J
R20	Resistor, fixed, 3600 ohms, 1/4 w		RC07GF362J
R21	Resistor, fixed, 10,000 ohms, 1/2 w		RC20GF103J
V1,2,3,4,5	Tube, electron		6CB6A
V6	Tube, electron		6AN5

APPENDIX C

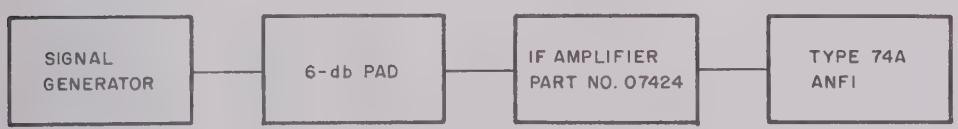
IF AMPLIFIER PART NO. 07424

1. SPECIFICATIONS

Frequency	30 Mc 40 to 180 Mc tunable
Band-Pass Ripple	Negligible
Bandwidth	2 Mc
IF Voltage Gain	35,000
IF Power Gain	69 db
Input Impedance	50 ohms
Load Impedance:	
Video (minimum)	100 k
Second Detector	100 ohms
Video Limiting Voltage	3.5 volts
Gain Control Range	65 db

2. ALIGNMENT PROCEDURE

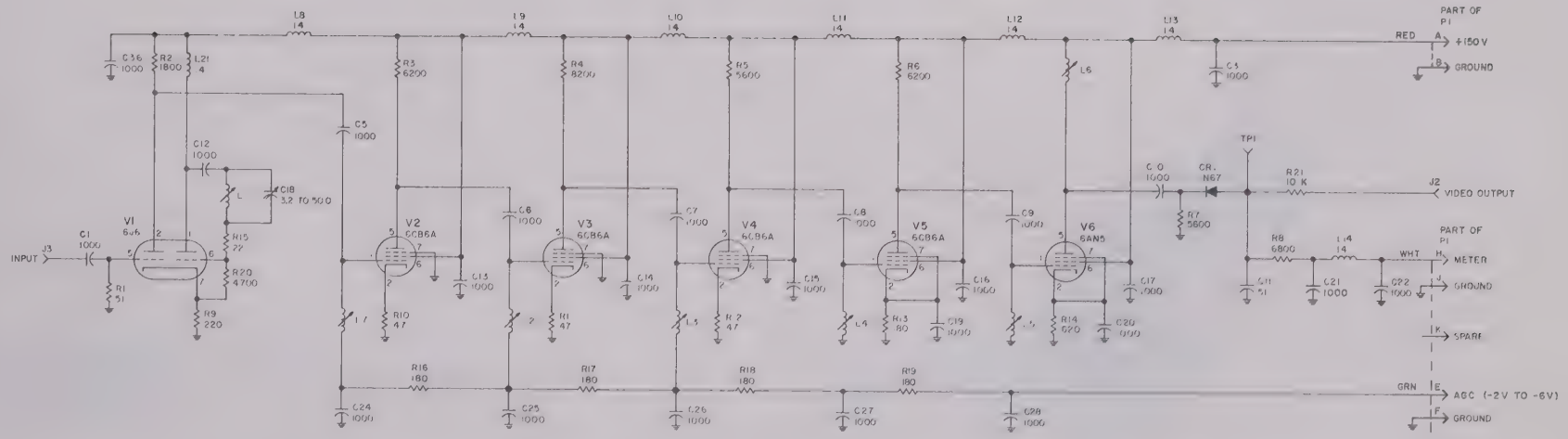
a. Set slugs of L3 and L5 fully out of coil.
b. Set slugs of L2 and L4 fully into coil.
c. Set slugs of L6 and L7 to approximate center of coil.
d. Set variable capacitor C18 to completely unmeshed position.
e. Connect equipment as shown below.



EQUIPMENT SETUP FOR IF AMPLIFIER 07424 ALIGNMENT

f. Align coils to following frequencies in sequence given. Set MANUAL GAIN on the Type 74A ANFI to mid-range. Adjust signal generator output so that second detector current on Type 74A ANFI is between 0.2 and 0.5 ma at all times.

Order of Alignment	Coil	Frequency (Mc)
1	L6	30.0
2	L7	30.0
3	L5	31.4
4	L4	28.7
5	L3	31.4
6	L2	28.7


INPUT
J3
V1 6J6
V2 6CB6A
V3 6CB6A
V4 6CB6A
V5 6CB6A
V6 6AN5
PART OF P1
RED
+150V
GROUND
VIDEO OUTPUT
J2
METER
WHT
SPARE
AGC (-2V TO -6V)
GRN
FILAMENT
BRN
TP1
CR1 N67
L8 L9 L10 L11 L12 L13 L14 L15 L16 L17 L18 L19 L20
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 R13 R14 R15 R16 R17 R18 R19 R20 R21
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21 C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

COIL NO.	ATL. DWG NO.	TUNING Mc
L1	114847	70 TO 150
L2	114818	28.7
L3	115353	31.4
L4	114818	28.7
L5	114818	31.4
L6	112240	30.0
L7	114818	30.0

UNLESS OTHERWISE NOTED:
RESISTANCE VALUES IN OHMS, ±5%, 1/2 WATT
CAPACITANCE VALUES IN PF
INDUCTANCE VALUES IN UH

SCHEMATIC DIAGRAM, IF AMPLIFIER 07424

3. REPLACEABLE PARTS LIST

Reference Symbol	Description	Manufacturer	Part Number
C1,2,3,5,6,7,8,9, 10,12,13,14,15,16, 17,19,20,21,22,24, 25,26,27,28,29,30, 31,32,33,34,35,36,	Capacitor, ceramic,1000 pf	Centralab	D6-402
C18	Capacitor, trimmer,3.2-50 pf	Hammer-Lund	MAPC-B50
C11	Capacitor, ceramic,51 pf	Erie	CC21UJ510J
CR1	Diode, crystal		1N67
L1	Coil, variable	AIL	114847
L2, 4, 5, 7	Coil, variable	AIL	114818
L3	Coil, variable	AIL	113333
L6	Coil, variable	AIL	112240
L8,9,10,11,12,13, 14,21	Inductor, 14 μh	Speers	10102-1
L15,16,17,18,19,20	Inductor, 1.1 μh	Speers	10101-1
R1	Resistor, fixed, 51 ohms, 1/2 w		RC20GF510J
R2	Resistor, fixed, 1800 ohms, 1/2 w		RC20GF182J
R3, 6	Resistor, fixed, 6200 ohms, 1/2 w		RC20GF622J
R4	Resistor, fixed, 8200 ohms, 1/2 w		RC20GF822J
R5, 7	Resistor, fixed, 5600 ohms, 1/2 w		RC20GF562J
R8	Resistor, fixed, 6800 ohms, 1/2 w		RC20GF682J
R9	Resistor, fixed, 220 ohms, 1/2 w		RC20GF221J
R10, 11, 12	Resistor, fixed, 47 ohms, 1/2 w		RC20GF470J
R13,16,17,18,19	Resistor, fixed, 180 ohms, 1/2 w		RC20GF181J
R14	Resistor, fixed, 620 ohms, 1/2 w		RC20GF621J
R15	Resistor, fixed, 22 ohms, 1/2 w		RC20GF220J
R20	Resistor, fixed, 4700 ohms, 1/2 w		RC20GF472J
R21	Resistor, fixed, 10 k, 1/2 w		RC20GF103J
V1	Tube, electron		6J6
V2, 3, 4, 5	Tube, electron		6CB6A
V6	Tube, electron		6AN5

APPENDIX D

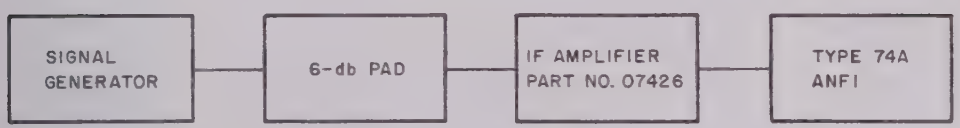
IF AMPLIFIER PART NO. 07426

1. SPECIFICATIONS

Frequency	60 Mc
Band-Pass Ripple	<1 db
Bandwidth	6 Mc
IF Voltage Gain	35,000
IF Power Gain	69 db
Input Impedance	50 ohms
Load Impedance:	
Video (minimum)	100 k
Second Detector	100 ohms
Video Limiting Voltage	3.5 volts
Gain Control Range	65 db

2. ALIGNMENT PROCEDURE

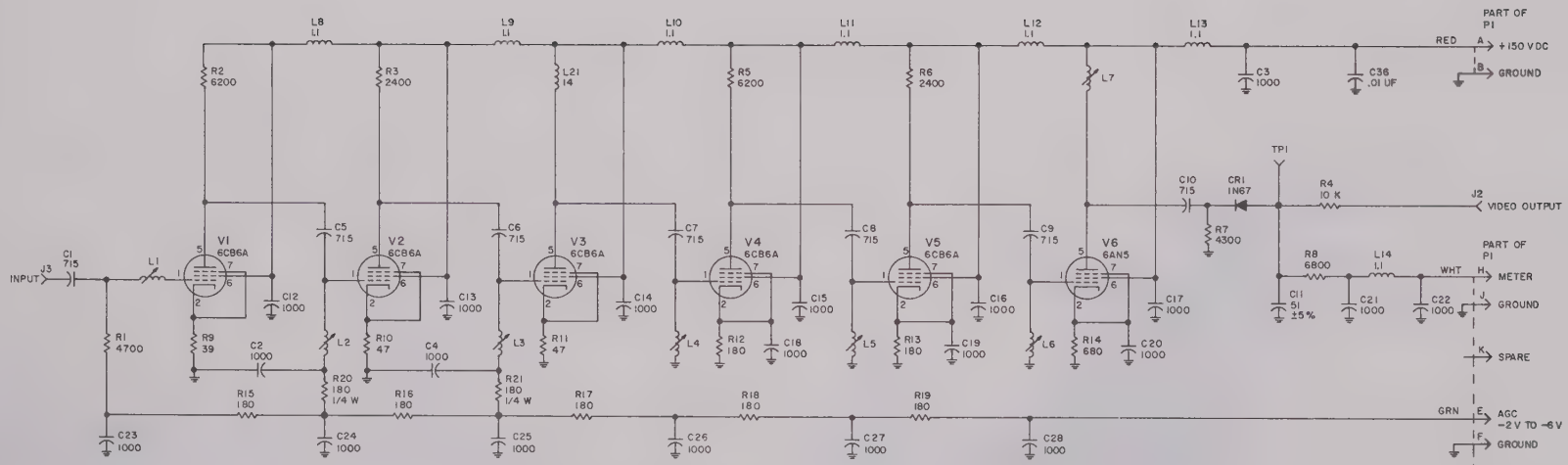
a. Set slugs of L2 and L4 fully out of coil.
b. Set slugs of L3, L5, and L7 fully into coil.
c. Set slugs of L1 and L6 to approximate center of coil.
d. Connect equipment as shown below.



EQUIPMENT SETUP FOR IF AMPLIFIER 07426 ALIGNMENT

f. Align coils to following frequencies in sequence given. Set MANUAL GAIN on Type 74A ANFI to mid-range. Adjust signal generator output so that second detector current on Type 74A ANFI is between 0.2 and 0.5 ma at all times.

Order of Alignment	Coil	Frequency (Mc)
1	L1	61
2	L2	63.5
3	L3	56.4
4	L4	63.5
5	L5	56.5
6	L6	59.6
7	L7	58



COIL NO.	A I L DWG NO.	TUNING Mc
L1	113590	61.0
L2	112243	63.5
L3	113590	56.4
L4	112243	63.5
L5	116232	56.5
L6	112243	59.6
L7	113590	58.0

UNLESS OTHERWISE NOTED:
RESISTANCE VALUES IN OHMS, ±5%, 1/2 WATT
CAPACITANCE VALUES IN PF, ±20%
INDUCTANCE VALUES IN UH

SCHEMATIC DIAGRAM, IF AMPLIFIER 07426

3. REPLACEABLE PARTS LIST

Reference Symbol	Description	Manufacturer	Part Number
C1,5,6,7,8,9,10	Capacitor, ceramic, 715 pf		117212-1
C35, 36, 38	Capacitor, disc, 0.01 pf		115302-1
C2,3,4,12-34,37	Capacitor, ceramic, 1000 pf		118049-3
C11	Capacitor, ceramic, 51 pf	Erie	CC21UU510J
CR1	Diode, crystal		1N67
L1, 3, 7	Coil, variable	AIL	113590
L2, 4, 6	Coil, variable	AIL	112243
L5	Coil, variable	AIL	116232
L21	Inductor, molded, 14 μh	Speers	10102-1
L8-20	Inductor, molded, 1.1 μh	Speers	10101-1
R1	Resistor, fixed, 4700 ohms, 1/2 w		RC20GF472J
R2, 5	Resistor, fixed, 6200 ohms, 1/2 w		RC20GF622J
R3, 6	Resistor, fixed, 2400 ohms, 1/2 w		RC20GF242J
R4	Resistor, fixed, 10,000 ohms, 1/2 w		RC20GF103J
R7	Resistor, fixed, 4300 ohms, 1/2 w		RC20GF432J
R8	Resistor, fixed, 6800 ohms, 1/2 w		RC20GF682J
R9	Resistor, fixed, 39 ohms, 1/2 w		RC20GF390J
R10, 11	Resistor, fixed, 47 ohms, 1/2 w		RC20GF470J
R12,13,15-19	Resistor, fixed, 180 ohms, 1/2 w		RC20GF181J
R14	Resistor, fixed, 680 ohms, 1/2 w		RC20GF681J
R20, 21	Resistor, fixed, 180 ohms, 1/2 w		RC20GF181J
V1,2,3,4,5	Tube, electron		6CB6A
V6	Tube, electron		6AN5